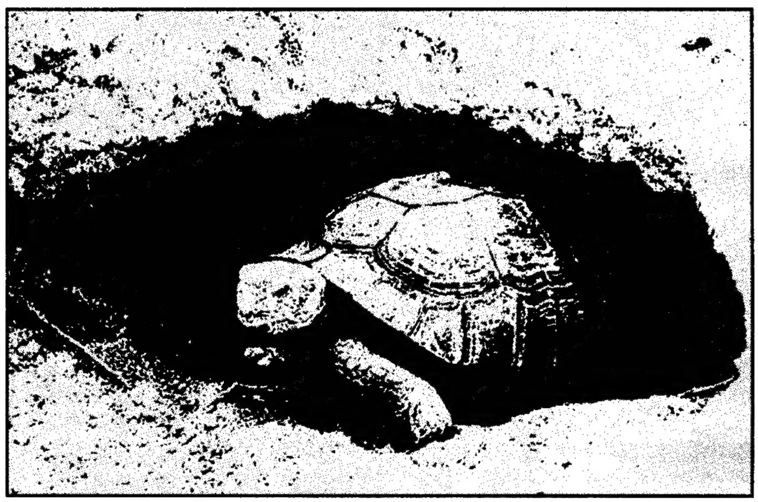
US Army Corps
of Engineers
Construction Engineering
Research Laboratories

USACERL Technical Report EN-94/10
September 1994

The Desert Tortoise at Fort Irwin, California

A Federal Threatened Species

by
Anthony J. Krzysik



Properly designed and implemented inventory, assessment, and monitoring programs are important components of environmental compliance for U.S. Army training installations. In earlier work, a statistically rigorous and quantitative assessment and monitoring program for arid and semi-arid ecosystems was developed and initiated in the Mojave Desert. The program was implemented in March 1983 at Fort Irwin, CA, the Army's National Training Center (NTC), to monitor woody perennial vegetation and vertebrate populations. Data from that program, and ongoing work by the author, have produced analytical capabilities to quantitatively assess the effects of training activities on ecosystems at landscape scales. Such assessments are needed to determine environmental mitigation and management priorities, and future monitoring and research needs.

This report discusses the ecology and biology of the Desert Tortoise—a Federal Threatened Species—its distribution and density patterns on Fort Irwin in 1989, and the effects of 6 years of the NTC mission on these patterns. Priorities and guidelines are discussed for environmental management and mitigation, based on sound ecological principles and the author's cumulative research on the Mojave Desert ecosystem.

Approved for public release; distribution is unlimited.

USER EVALUATION OF REPORT

REFERENCE: USACERL Technical Report EN-94/10, *The Desert Tortoise at Fort Irwin, California*

Please take a few minutes to answer the questions below, tear out this sheet, and return it to USACERL. As user of this report, your customer comments will provide USACERL with information essential for improving future reports.

1. Does this report satisfy a need? (Comment on purpose, related project, or other area of interest for which report will be used.)

___

___

___

2. How, specifically, is the report being used? (Information source, design data or procedure, management procedure, source of ideas, etc.)

___

___

3. Has the information in this report led to any quantitative savings as far as manhours/contract dollars saved, operating costs avoided, efficiencies achieved, etc.? If so, please elaborate.

___

___

4. What is your evaluation of this report in the following areas?

   a. Presentation: ___

   b. Completeness: ___

   c. Easy to Understand: ___

   d. Easy to Implement: ___

   e. Adequate Reference Material: ___

   f. Relates to Area of Interest: ___

   g. Did the report meet your expectations? ___

   h. Does the report raise unanswered questions? ___

i. General Comments. (Indicate what you think should be changed to make this report and future reports of this type more responsive to your needs, more usable, improve readability, etc.)

____

____

____

____

____

____

5. If you would like to be contacted by the personnel who prepared this report to raise specific questions or discuss the topic, please fill in the following information.

Name: ______________________________

Telephone Number: ______________________________

Organization Address: ______________________________

____

____

6. Please mail the completed form to:

Department of the Army
CONSTRUCTION ENGINEERING RESEARCH LABORATORIES
ATTN: CECER-TR-I
P.O. Box 9005
Champaign, IL 61826-9005

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1994	Final

4. TITLE AND SUBTITLE
The Desert Tortoise at Fort Irwin, California: A Federal Threatened Species

5. FUNDING NUMBERS
MIPR
FE018-91,
dated 29 March 1991

6. AUTHOR(S)
Anthony J. Krzysik

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Construction Engineering Research Laboratories (USACERL)
P.O. Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
EN-94/10

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Headquarters, U.S. Army Forces Command (FORSCOM)
ATTN: FCEN-RDF
Fort McPherson, GA 30330-6000

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The U.S. Department of Defense has the legal responsibility for managing the natural resources on its training lands, and the Department of the Army has made a commitment to become exemplary in issues of environmental compliance. Properly designed and implemented inventory, assessment, and monitoring programs are important components of environmental compliance. In earlier work, a statistically rigorous and quantitative assessment and monitoring program for arid and semiarid ecosystems was developed. The program was implemented in 1983 at Fort Irwin, CA, to monitor perennial woody vegetation and vertebrate populations. Data from that program, and ongoing work by the author, have produced analytical capabilities to assess the effects on the Mojave Desert ecosystem of Army training activities at the National Training Center (NTC) at Fort Irwin. Such an assessment is needed to determine environmental mitigation and management priorities, as well as future monitoring and research needs.

This report describes the geophysical characteristics and environment of Fort Irwin, describes the Army training mission at the NTC, and summarizes the effects of the military training mission at Fort Irwin on woody vegetation and vertebrate fauna. Priorities for environmental mitigation, management, research, and monitoring at NTC—based on the author's cumulative work in this area—are discussed.

14. SUBJECT TERMS
desert tortoise
desert ecology
Fort Irwin, CA
threatened species

15. NUMBER OF PAGES
102

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std 239-18
298-102

Foreword

This study was conducted for Headquarters, U.S. Army Forces Command (FORSCOM) under Military Interdepartmental Purchase Request (MIPR) No. FE018-91, dated 29 March 1991; Reimbursable Work Unit "Army Training Activities at the National Training Center and Their Effects on Wildlife and Their Habitats." The technical monitor is Stuart Cannon, FCEN-RDF.

The work was performed by Environmental Natural Resources Division (EN) of the Environmental Sustainment Laboratory (EL), U.S. Army Construction Engineering Research Laboratories (USACERL). Dr. William Severinghaus is Chief, CECER-EN, and Dr. William Goran is Chief, CECER-EL. Thomas Clark, Bureau of Land Management, Barstow (CA) Resource Area Office, is acknowledged for his work as installation technical monitor on this project in his previous position as Ecologist for Fort Irwin. The USACERL technical editor was Gordon L. Cohen, Information Management Office.

LTC David J. Rehbein is Commander and Acting Director, USACERL, and Dr. Michael J. O'Connor is Technical Director.

Contents

List of Figures and Tables

Figures

Tables

1 Introduction

Background

The U.S. Department of Defense (DOD) has the legal responsibility for managing the natural resources on its training lands, and the Department of the Army has made a commitment to become exemplary in issues of environmental compliance. Strongly pertinent environmental mandates and documents include the *National Environmental Policy Act (NEPA)*, *Endangered Species Act*, *Clean Water Act*, *Migratory Bird Conservation Act*, Executive Orders 11990 (Protection of Wetlands) and 11988 (Floodplain Management), and Army Regulations (AR) 200-2, AR 420-74, and AR 420-76.

Important components of Army environmental compliance programs are properly designed and implemented inventory, assessment, and monitoring programs. In earlier work the author researched and developed a statistically rigorous quantitative assessment and monitoring program for arid and semiarid ecosystems (Krzysik 1984, 1985, 1987). The program was implemented in March 1983 at Fort Irwin, CA, the Army's National Training Center (NTC) to monitor woody perennial vegetation and vertebrate populations. Data from that program and ongoing research and development by the author have developed analytical capabilities to quantitatively assess the effects of military training activities on ecological communities and ecosystems at landscape scales.

Populations of the Desert Tortoise—a Federal Threatened Species—are experiencing serious declines in the Mojave Desert, particularly in the western Mojave (Kristin Berry, National Biological Survey, personal communication, 1990). The primary known threats are urbanization, off-road vehicles (ORVs), upper respiratory tract disease (URTD), and vandalism. Grazing by sheep and cattle, and raven predation on hatchlings and juveniles may also be contributing to tortoise declines—particularly in local populations—but the data are controversial and research continues. Military training has had a long history in the Mojave Desert, and it has undoubtedly affected tortoise populations both by habitat destruction and direct mortality (Krzysik 1993).

Objectives

The objectives of this report are to:

1. briefly describe the geophysical characteristics and environment of Fort Irwin
2. summarize the history of the military mission and current land use at Fort Irwin
3. summarize the biological and ecological parameters that affect the Desert Tortoise
4. analyze in depth the 1989 distribution and density patterns of the Desert Tortoise at Fort Irwin
5. assess the effects of the NTC mission on the distribution and density patterns of the Desert Tortoise by statistically comparing the observed 1989 patterns to those found in 1983
6. discuss priorities and options for management, mitigation, monitoring, and research, based both on the current research and the author's cumulative experience in this area.

Approach

The author summarized pertinent observations and published findings from his previous research on the plant and animal communities of Fort Irwin. To support those observations and findings, the author conducted a comprehensive literature survey pertaining to plant and animal communities naturally occurring within desert environments in the vicinity of Fort Irwin, including migratory species that may use any part of the installation during part of their life cycle (Krzysik 1994a).

Training activities at Fort Irwin were described and quantified, with special attention to the force-on-force battle exercises conducted regularly at Fort Irwin's National Training Center. The author's previous research and all other pertinent literature were surveyed to compile a summary of both the known and potential effects of training activities on Fort Irwin's Desert Tortoise populations.

Scope

Although the assessment and monitoring program was developed for arid ecosystems and initially implemented in the Mojave Desert, the overall concept, approach, experimental and sampling design, and statistical analyses are directly applicable to any ecosystem. Of course, details of sampling design and field methods will differ

because these directly depend on ecosystem type and the specific objectives of assessment and monitoring (including desired accuracy and precision).

This report, and companion reports on (1) biodiversity and threatened/endangered/ sensitive species at Fort Irwin (Krzysik 1994a) and (2) the State threatened Mohave* Ground Squirrel (Krzysik 1994b) were motivated by extensive biological (Krzysik 1990) and ecological (Krzysik 1991) assessments conducted by the author at Fort Irwin for the NTC and U.S. Army Forces Command (FORSCOM).

* Although the name of the desert is spelled with *j*, the name of the ground squirrel is correctly spelled with an *h*.

2 Site and Setting

Geography and Physiography

Fort Irwin is located in San Bernardino county in southeastern California, about 65 km northeast of Barstow, CA. Most of the land surrounding the fort is public land managed by the U.S. Bureau of Land Management (BLM). The western boundary is adjacent to Naval Air Weapons Station, China Lake (NAWS) (Mojave B Ranges). The southern boundary of Death Valley National Monument is close to the northeast boundary of the fort. Fort Irwin is in the Basin and Range geologic province. Structural features of the landscape formed in the Cenozoic Era, about 40 million years ago, from movements related to the San Andreas and Garlock faults.

Physiographically Fort Irwin is located in the central Mojave Desert. This region is characterized by rugged block-faulted mountain ranges separated by alluvium filled basins. The basins consist of broad valley plains, gentle sloping bajadas (ancient coalesced alluvial fans), and rolling hills with low relief. The lowest basins form playas (dry lake beds). The eroding mountains produce talus slopes, boulder fields, and rocky or gravelly alluvial fans (pediments) that merge into the sandy soils and fine gravels of bajadas and plains. A dominant visual feature of the landscape, especially impressive from an aerial view, are the extensive and complex dendritic networks of canyons, arroyos, and washes. Washes often form extensive networks of braided channels on bajadas with low relief. Other common features of the landscape include rolling hills with gravelly or rocky substrates, highly fractured boulder ridges, rugged boulder/rock outcrops of granite or volcanic basalt, desert pavement, and sand dunes. Springs and seeps are uncommon occasional features of the Mojave Desert landscape.

Five mountain ranges (or portions of them) are located within the boundaries of Fort Irwin: Granite, Tiefort, Avawatz, Quail, and Paradise. The foothills of three additional mountain ranges fall along the fort's boundaries: Alvord, Soda, and Owlshead. Approximately 60 percent of Fort Irwin consists of bedrock at or near the surface. The remaining 40 percent is underlain by alluvial and lacustrine deposits.

Additional details about the geophysical setting, biological environment, and ecology of Fort Irwin can be found in Krzysik 1994a.

Military Training Activities

Fort Irwin consists of three management units: the National Training Center (NTC), the Goldstone Deep Space Communications Complex, and Leach Lake Bombing Range (Figure 1). Fort Irwin is 2600 sq km in area (1004 sq mi), about the size of Rhode Island. The Goldstone complex (135 sq km) is leased and operated by the National Aeronautics and Space Administration (NASA) and the Jet Propulsion Laboratory (JPL). The Leach Lake Bombing Range (369 sq km) is leased to George Air Force Base.

Before the NTC was established, the Fort Irwin landscape was subjected to a cumulative total of 35 years of military training activities. The War Department withdrew public lands in 1940 and established the Mojave Army Antiaircraft Range. The installation was renamed Camp Irwin in 1942. During this period General George S. Patton's armored division of the Third Army trained at the installation and elsewhere in the California Desert. The post was placed on surplus status in 1947, but was reactivated in 1951 for training troops during the Korean conflict. Camp Irwin was redesignated 1 August 1961 as the Fort Irwin Armor and Desert Training Center. Between 1972 and 1980 it was used as a training area for the California Army National Guard. Fort Irwin was selected as the Army's National Training Center in

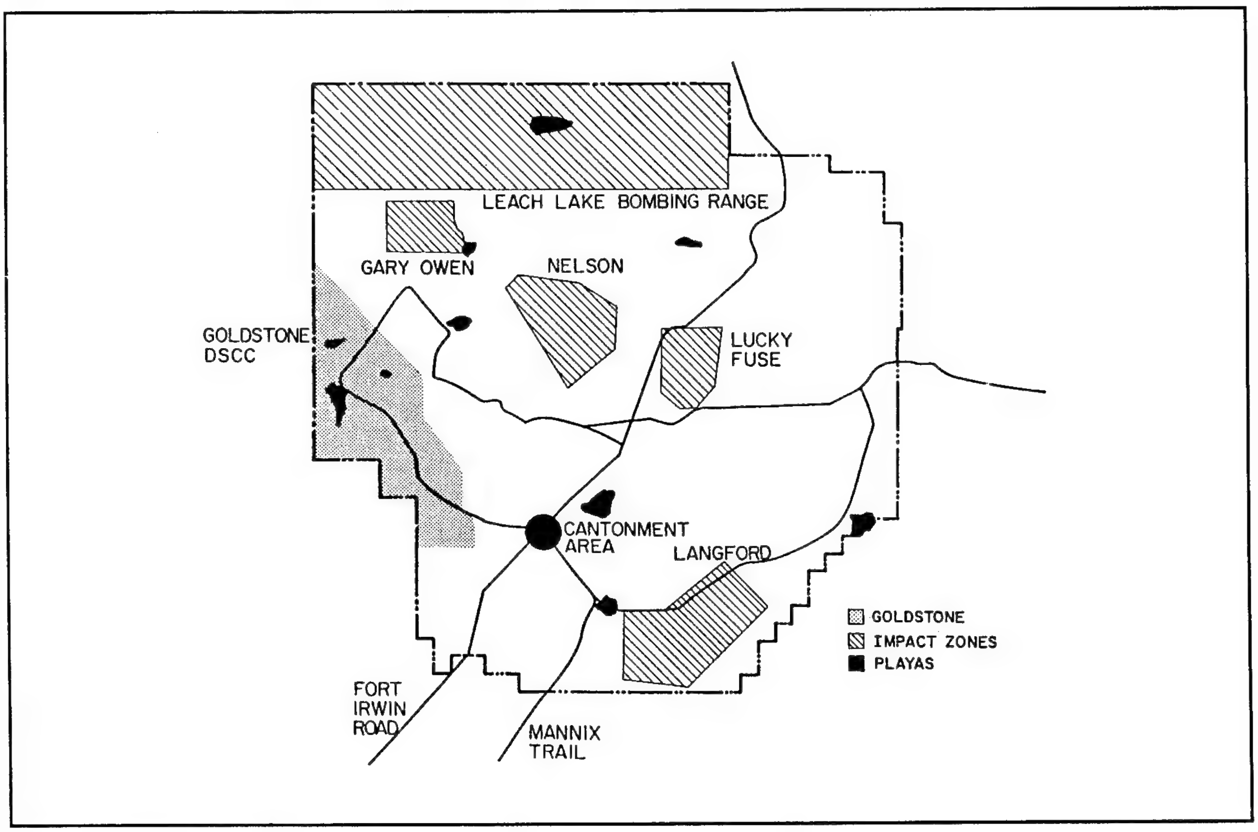


Figure 1. Map of Fort Irwin.

August 1979. The first NTC training exercise took place 13 April 1981, while the official reactivation ceremony was held 1 July 1981. NTC's massive force-on-force training exercises did not begin until 17 January 1982. At present the California National Guard occasionally trains on weekends between scheduled NTC training rotations.

Goldstone is off limits to Army training activities, but a tank trail constructed in 1985 bisects most of the installation. Vehicle use by Goldstone personnel is confined to paved and maintenance roads. Off-road vehicle use is minimal since public access is denied. However, Army tactical vehicles occasionally stray off the Goldstone tank trail. The Leach Lake Bombing Range is continually used for Air Force live-bomb practice, and is therefore off limits for ground use because of the high risk of unexploded ordnance. Military and civilian personnel working near the bombing range have reported detonations induced by rapid temperature changes.

Typical NTC rotational training exercises consist of realistic war games and battle scenarios where American forces, represented by visiting rotational units, engage enemy forces (NTC personnel), with both sides using eye-safe computer encoded laser beams to simulate bullets, missiles, and artillery projectiles. All tactical vehicles and soldiers are equipped with multiple sensors to count laser hits. All components of the exercises, including laser fire and hits, are directly incorporated into an extensive computer network that analyzes in detail tactical strategies and results. Another major component of a rotational group's training responsibilities is the live-fire exercises, which employ both stationary targets and moving, and pop-up targets. All weapons systems are used: small arms fire, armored vehicle cannons and automatic weapons, mortars, grenades, and antitank missiles. Two books are available describing actual battles and the rotational training exercises at the NTC (Bolger 1986, Halberstadt 1989).

Figure 2 shows the intensity of Army training activities at Fort Irwin, based on the number of annual tracked-vehicle-days since the initiation of NTC training scenarios. Note the large increase in training intensity since 1985. Tracked vehicles include tanks, armored personnel carriers, and armored fighting vehicles like the Bradley. The ratio of wheeled to tracked vehicles is approximately 3:1. Figure 3 shows the cumulative increase in the number of tracked vehicles used at the fort. Note the geometric increase in training intensity between 1981 and 1989.

Additional details about the NTC military mission and its effects on biological resources can be found in Krzysik (1994a). An analytical assessment of the effects of Army training activities on the central Mojave Desert ecosystem at Fort Irwin can be found in Krzysik 1984 and Krzysik 1985.

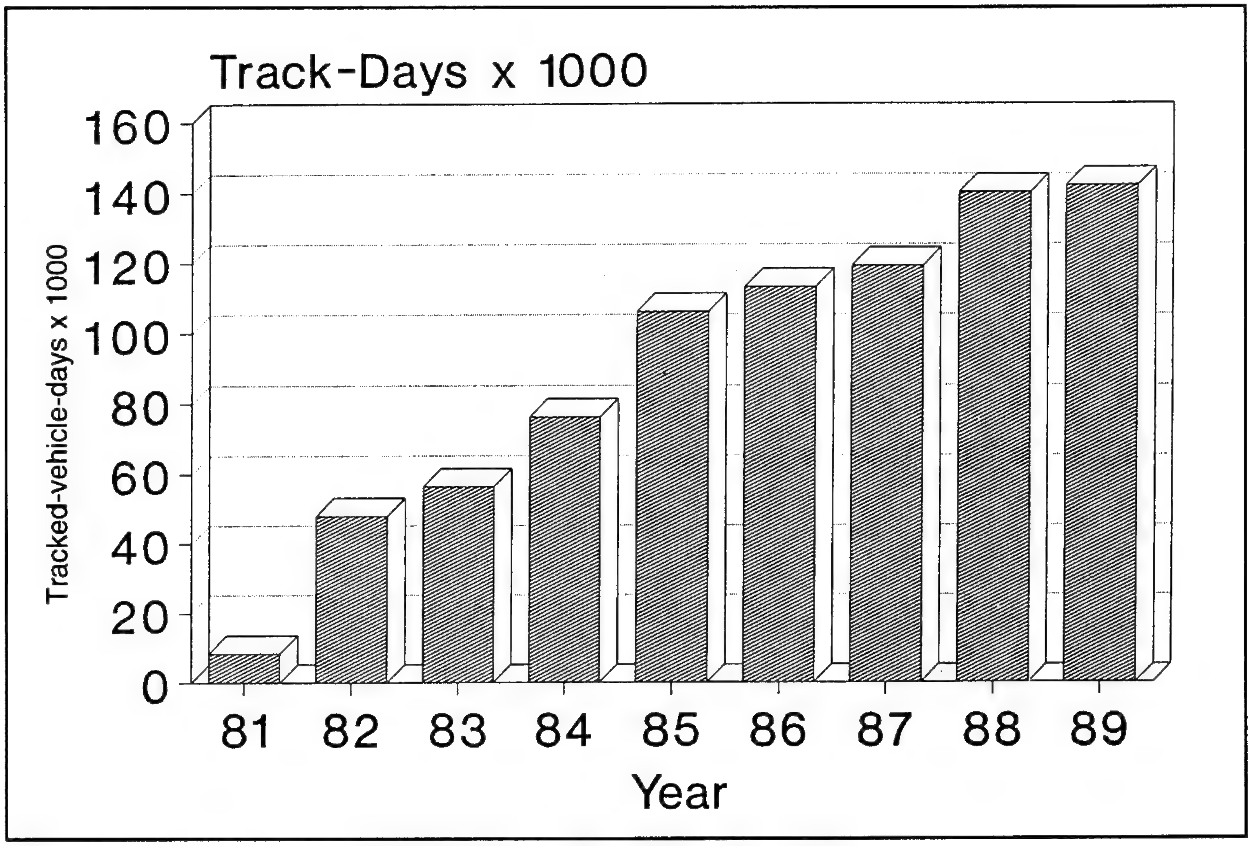


Figure 2. Annual number of tracked-vehicle-days at NTC, 1981 through 1989.

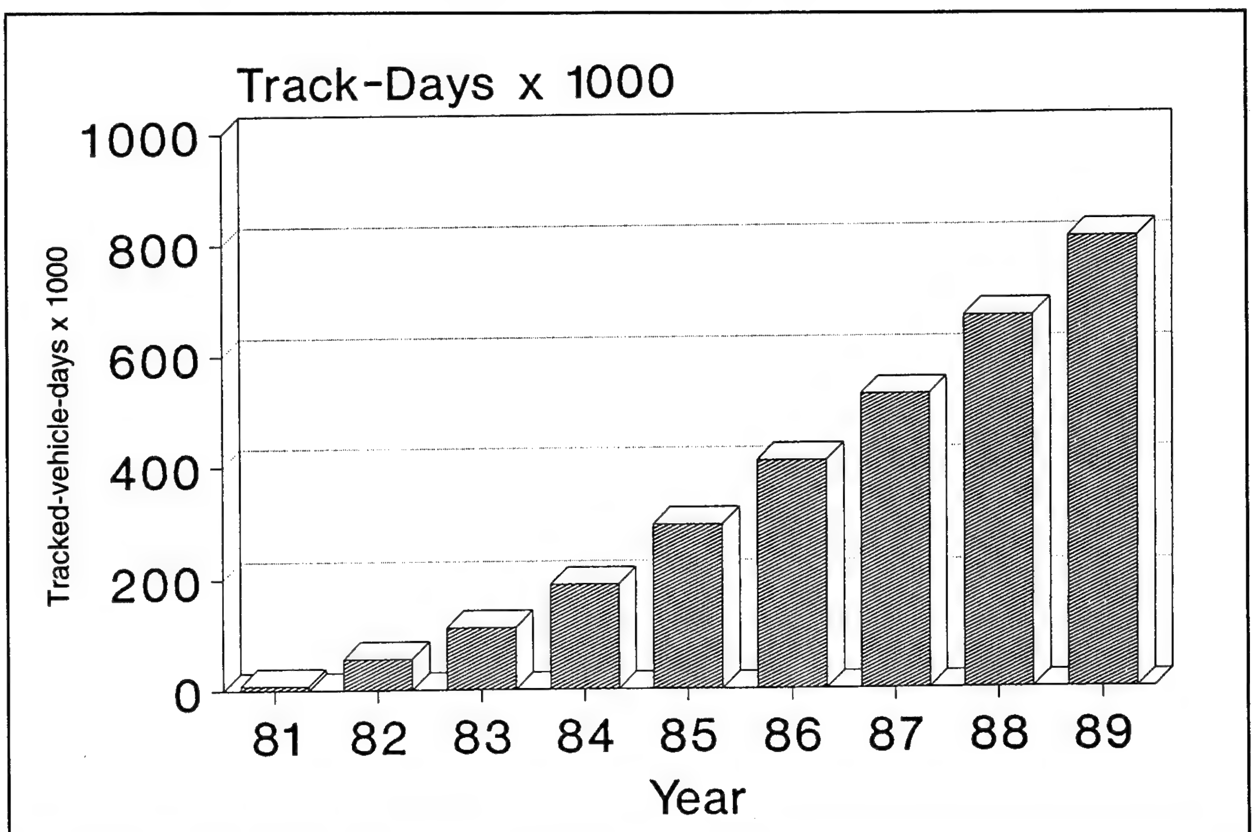


Figure 3. Cumulative tracked-vehicle-days at NTC, 1981 through 1989.

3 Biological and Ecological Parameters Affecting the Desert Tortoise

The Desert Tortoise has been known by three generic names (Gopherus, Scaptochelys, and Xerobates), and several minor spelling deviations of its species name have appeared in the literature. Current preference is Gopherus agassizii (Crumly 1984, 1988; King and Burke 1989).

It is currently believed that Desert Tortoise populations in the Mojave Desert are seriously declining and becoming fragmented. Many reasons have been reported (see "Population Trends" later in this chapter):

- habitat loss
- disease
- predation
- competition
- vandalism
- drought
- construction of roads and utility corridors.

Habitat losses have been direct, primarily from urbanization and agriculture, but also from energy development projects, waste disposal sites, mining, and military activities. Habitats have also been degraded to varying degrees by off-road vehicles and other recreation (also associated with urbanization), and grazing both by sheep and cattle. A highly infectious fatal upper respiratory tract disease (URTD) has rapidly spread through some tortoise populations. Released captives infected with the disease are believed to be responsible. Some nesting ravens have been reported to feed excessively on hatchling and juvenile Desert Tortoises. Raven populations are believed to be dramatically increasing in the Mojave Desert as a direct consequence of human settlement. Because cattle, sheep, and tortoises forage on the same grasses and annuals, it has been strongly suggested that tortoises compete with grazing stock. Vandalism includes outright shooting of live tortoises, and capture of tortoises for pets or eating. Accidental deaths also undoubtedly occur from off-road vehicles. The Desert Tortoise feeds extensively on winter annuals in the spring. The germination of winter annuals is highly dependent on winter rainfall, and annuals are not available in drought years—particularly when the drought spans several consecutive years. The

middle and late 1980s were unusually dry years, even for the Mojave Desert. Roads and utility corridors directly destroy habitat, and there is widespread belief among tortoise researchers that tortoise densities decline in a 1 km band on either side of a road because of vehicle mortality.

The introduction of exotic species into native ecosystems, whether on purpose or by accident, has been identified as a major cause for the deterioration and extinction of native populations and impacts to ecological processes (Mooney and Drake 1986; Miller et al. 1989; Reid and Miller 1989; Hobbs and Huenneke 1992). However, exotic species —with the possible exception of cattle and sheep—do not appear to have affected Desert Tortoise populations. Tortoises forage on exotic annuals, but the impact of these exotics on native ecosystems is unknown, and may remain unknown because baseline data are lacking.

Because of these threats to the Desert Tortoise, especially urbanization, off-road vehicles, and the spread of the fatal URTD, the U.S. Fish and Wildlife Service, under the emergency rule listing, listed the Desert Tortoise as an Endangered Species in the Federal Register on 4 August 1989. A proposal to make the emergency classification permanent was published 13 October 1989. This listing only applied to tortoise populations west and north of the Colorado River, the Mojave population. The two major provisions of the Endangered Species Act are the prohibition on killing or collecting tortoises without a permit, and the requirement that Federal agencies avoid activities that are likely to jeopardize tortoise survival. On 2 April 1990 the Fish and Wildlife Service listed in the Federal Register the Mojave population of the Desert Tortoise as Threatened. There are no fundamental differences between the classification Endangered or Threatened relating to Federal agency responsibilities for the protection or management of a listed species.

Habitat Conservation Planning (HCP) has become an important mechanism in bringing together Federal agencies, research scientists, grassroots conservationists, land developers, other economic concerns, and concerned citizens for planning detailed strategies for providing habitat for threatened and endangered species (Peter Brussard, Head of the Desert Tortoise Recovery Plan, personal communication, 1994; Beatley 1994). Important examples concerning the Desert Tortoise are the Clark County HCP (Beatley 1994) and the Washington County HCP (Scott Belfit, BLM Tortoise Biologist, personal communication, 1994). These HCPs activities are in response to the rapid urban growth of Las Vegas, NV, and St. George, UT, respectively.

Food Habits

Desert Tortoises are herbivores. The peak of their spring activity period coincides with the bloom of winter annuals. The germination of these succulent annuals in the spring depends on winter rainfall, the rainy season in the Mojave Desert. Tortoises preferentially feed on annual forbs, especially the flower portions (Luckenbach 1982). Luckenbach (1982) lists 27 species or genera of annual forbs that he has observed Desert Tortoises feeding on in California. Common examples on Fort Irwin include: Erodium cicutarium, Amsinckia tessellata, Chaenactis fremontii, Coreopsis bigelovii, Malacothrix glabrata, Eriophyllum wallacei, Astragalus lentiginosus, Monoptilon bellioides, Phacelia tanacetifolia, Phacelia sp., Baileya sp., Oenothera sp. (Camissonia sp. in part), Abronia sp., Mentzelia sp., Gilia sp., Rafinesquia sp., and others. Plantago insularis, a common annual on Fort Irwin, was reported by Burge and Bradley (1976) to be the most important spring-through-fall forage item for a Nevada population of the Desert Tortoise. Turner et al. (1984) found that the annuals Cryptantha sp. and Pectocarya sp. constituted 65 to 74 percent of the dry biomass of forbs at their Ivanpah Valley study plot in the eastern Mojave Desert. These genera were identified in tortoise scat along with Nama demissum and other genera listed by Luckenbach. All three taxa are also common on Fort Irwin.

Esque (1994) conducted a quantitative detailed field observational study of the feeding preferences of the Desert Tortoise in the northeast Mojave Desert. The study was conducted during the spring (April through June) at two sites—one in southwest Utah for 4 years, and one in northwest Arizona for 3 years. Tortoises sampled about 50 percent of available plant species at each of the two sites. Although this comprised approximately 50 species, three to five annual species made up the bulk of their diets. Annual forbs were primarily consumed in early spring while annual grasses predominated in the late spring. This trend paralleled forage availability in the habitat. Both native and exotic species were common in tortoise diets. Important native species were Plantago patagonica, P. insularis, Stephanomeria exigua, and Descurainia pinnata. Important exotics were Bromus rubens, B. tectorum, Erodium cicutarium, and Schismus barbatus. Esque concluded that although common species in the habitat were selected by the Desert Tortoise, there was not a consistent pattern in diet selection among the years of the study.

Jennings and Fontenot (1992) conducted a study on the forage preferences of two adult (male and female) Desert Tortoises in the western Mojave Desert. They also reported that tortoises preferred annual plants over perennials—71 percent of bites recorded and 81 percent of species. Native species were consumed more frequently than exotics—88 percent of bites recorded and 70 percent of plants. In contrast to Esque's (1994) study, Jennings and Fontenot tortoises selected rare or uncommon species in

the habitat (e.g., Astragalus layneae and other legumes). However, an important consideration in the Jennings and Fontenot study is the small sample size and the resulting potential for severe bias.

These examples—others could be discussed—illustrate that foraging ecology of the Desert Tortoise and its biogeographic implications are complex and require further comparative investigations.

During the hot and dry Mojave Desert summer, annual forbs are absent or scarce, and the Desert Tortoise feeds on grasses. Luckenbach (1982) reported that the exotic annual grasses Schismus sp. and Bromus rubens are commonly eaten, as is the native perennial, galleta grass (Hilaria rigida*). During the course of the field work for this study, Peter Woodman and the author conducted tortoise surveys on Fort Irwin and examined numerous tortoise scats. It was obvious that galleta grass was the predominant forage for Desert Tortoises. There have been several years of drought in this part of the Mojave Desert, and dry grasses were the primary herbaceous vegetation available in the desert scrub. Avery (1992) studied Desert Tortoise food habits during the summer (August–September) in the eastern Mojave Desert and concluded that 98 percent of the 1829 total bites observed in the field were concentrated on annual grama grasses (Bouteloua aristidoides and B. barbata). During an exceptionally dry year, Turner et al. (1984) reported that during the summer, cactus pads and fruit were the primary forage for tortoises. With the exception of galleta grass and beavertail cactus (Opuntia basilaris), Luckenbach (1982) reported that he has never seen a Desert Tortoise feeding on desert perennials. However, in Nevada, Burge and Bradley (1976) reported that the second most important food item for tortoises was Sphaeralcea ambigua, a semishrub that becomes woody as it ages and grows. This species is also common on Fort Irwin. Other perennials used by the Desert Tortoise in Nevada that are also common on Fort Irwin include Eriogonum inflatum, Krameria parvifolia,** Stephanomeria pauciflora, and two cacti—Opuntia ramosissima and Echinocactus polycephalus. Turner et al. (1984) also reported finding in tortoise scats small amounts of woody perennials that represent species abundant and widespread on Fort Irwin: Ephedra, Larrea, Krameria, Grayia, and Lycium. Esque (1994) reported that Krameria was the main perennial in the diets of tortoises in the northeast Mojave Desert, but—as discussed above—tortoises primarily consumed annual plants.

Other than their predictable presence, even when desiccated, perennial forbs and shrubs are not favored forage items for the Desert Tortoise, and may be eaten only

---

* now designated as Pleuraphis rigida (Hickman 1993).

** now designated as Krameria erecta (Hickman 1993).

when preferred items are absent. The importance to the Desert Tortoise of the availability, quality, and species composition of these persistent perennials in the habitat during drought years is unknown. With the known exception of grasses and cacti, perennials may not be commonly eaten by Desert Tortoises, because these plants are not as palpatable or digestible. Also, they may contain excess salts, toxins, or aversive compounds, or some combination of the three. In general, because of contrasting life history strategies, annuals partition a major allotment of their resources into seed production, while perennials channel resources into the production of toxins and allelopathic chemicals.

Reproduction

Peak mating activity for the Desert Tortoise in the Mojave Desert has been reported as March to June (Luckenbach 1982), and August and September (Burge 1977). Berry (1975) observed mating throughout the activity season, with peaks occurring in the spring and fall. Mating has been observed as late as October (Tomko 1972; Berry 1975; Burge 1977).

Most of the information about the reproductive biology of Desert Tortoises has been obtained from captive individuals (Grant 1936; Stuart 1954; Miller 1955). Tortoises deposit their eggs in nests dug in the soil. Eggs are primarily deposited from May through July (Ernst and Barbour 1972; Luckenbach 1982). Tortoises laid eggs in May and June in two populations studied in the eastern Mojave Desert: Ivanpah Valley (Turner et al. 1984), and Goffs (Turner et al. 1986).

Clutch size in lizards and snakes is closely related to body size (Fitch 1970). Relationships between clutch size and body size in aquatic turtles exist in some species (Gibbons 1982; Gibbons et al. 1979, 1982; Congdon and Gibbons 1983). Carapace length and egg numbers are positively correlated in the Gopher Tortoise (Landers et al. 1980), Berlandier's Tortoise (Rose and Judd 1982), and the Desert Tortoise (Turner and Berry 1985). Clutch size in the Desert Tortoise generally varies between 2 to 14 eggs (Grant 1936; Ernst and Barbour 1972). Wild tortoises typically lay 4 to 6 eggs, which is generally less than are reported for captive tortoises (summarized in Hohman et al. 1980). Turner et al. (1986) reported that 88 percent of the Goffs population clutches contained 3 to 6 eggs (range 1 to 8), with a mean of 4.5 and a median of 4. They found that females in the Goffs population averaged smaller clutches than in other populations. Sexually mature females in this population also possessed next to the shortest mean carapace length of the 16 California and Nevada populations listed by Berry (1984, Table 2, p A5-5).

Captive Desert Tortoises have produced two or three egg clutches in a year (Stuart 1954; Miller 1955). Laying several smaller clutches over the reproductive season instead of depositing a single large one may be an adaptive strategy to minimize egg predation. Turner et al. (1984) reported that at Ivanpah Valley, 11 of 15 females had two clutches in 1980, and 12 of 40 females double clutched in 1981. Rainfall and plant production in 1981 was unusually low. Turner's technique of periodically weighing females to detect egg laying may not be consistently accurate. Turner et al. (1986) used x-rays to detect egg development in females at the Goffs population, and reported that 16 of 19 tortoises laid 2 to 3 clutches in 1983, as did 14 of 23 in 1984, and 14 of 20 in 1985. Multiple clutches were significantly correlated with larger females. Eleven tortoises laid eggs in each of the 3 years of the study. Even with the very poor production of annual plants and grasses at Ivanpah Valley in 1981, 32 of 40 female tortoises deposited at least a single clutch (Turner et al. 1984). In a 1990 tortoise study at the southern portion of Fort Irwin, 22 gravid females (out of a total of 47 captured) were released into a 60 m^2 predator-proof enclosure (Joyner-Griffith 1991) After oviposition (depositing their eggs) the tortoises were returned to their original collection site. Fifty-seven out of the 59 eggs laid inside the enclosure hatched. Mean clutch size was 2.7. Mean size and weight of the neonates (newborn tortoises) were 48.4 mm and 28.5 g, respectively.

Desert Tortoise eggs hatch from mid-August to October, with the peak being in September to early October (Ernst and Barbour 1972; Hohman et al. 1980). Grant (1936) reported that from a June clutch laid in captivity, four eggs hatched in November, while one egg overwintered in the nest and hatched the following spring. The reported incubation period for Desert Tortoise eggs is highly variable for both wild and captive clutches, ranging from about 90 to 135 days for wild tortoises, and 83 to 150 days for captive tortoises (Hohman et al. 1980; Luckenbach 1982). Artificially incubated eggs generally hatch in 80 to 90 days (Lampkin 1966; Shade 1972). Hatching success is commonly less than 60 percent (Hohman et al. 1980, Luckenbach 1982). Hatchlings possess a carapace 36 to 48mm long and 35 to 43mm wide (Ernst and Barbour 1972). Krzysik found a hatchling at Fort Irwin on 17 September 1989 in the southwestern portion of the Langford Impact area (UTM* coordinates 386896). Its carapace length was 46mm and the width was 39mm.

Nest site selection in The Desert Tortoise may select its nesting site near or inside summer dens, at the mouth of winter dens, or at a pallet (Hohman et al. 1980; Dave Morafka, Professor, California Statue University at Dominguez Hills, personal communication, 1990). (Pallets are surface retreats constructed by Desert Tortoises in thick, dense shrubbery. Krzysik observed a predated nest located beneath Mormon

* UTM: Universal Transverse Mercator.

tea (Ephedra californica) at the edge of a large sandy wash. Pallets are commonly constructed within Mormon tea at Fort Irwin.

The age for sexual maturity of the Desert Tortoise is 15 to 20 years or more (summarized in Hohman et al. 1980). A good average to use is 18 years, with a variability of 12 to 25 (Todd Esque, NBS tortoise researcher, personal communication, 1994). Secondary sexual characteristics of males first appear when they are 16 years old, become more obvious at 17, and are complete at 20 (Miller 1955). These include a longer, more upward-curved gular, a concave depression in the plastron, more vertical drop at the posterior outline of the carapace, heavier claws, and a longer, thicker tail. These morphological characteristics are more evident and pronounced in older and larger tortoises. Woodbury and Hardy (1948) reported that at the Beaver Dam Slope in southwestern Utah, sexual maturity was reached at 15 to 20 years of age. Male tortoises were larger than females. Adult males were 250 to 309 mm in length, while females were 230 to 265 mm in length. Seasonal growth of Desert Tortoises in the Mojave Desert is highly variable and strongly dependent on the winter rainfall. Over a 10-year period the mean annual growth for 22 tortoises 3.3 to 10.1 years old in southern Nevada was 9.1 mm (range: 4.3 to 14.4 mm/yr) (Medica et al. 1975). Smaller and younger tortoises grow faster than older individuals. Woodbury and Hardy (1948) believed that after reaching maturity, Desert Tortoises do not appreciably increase in size. A female tortoise brought into captivity as an adult in 1923 grew very little until the time of her death in 1982 (Glenn 1983). A 3-year-old captive tortoise brought in as a hatchling at Marine Corps Air Ground Combat Center (MCAGCC), in the southern Mojave Desert, has reached a carapace length of 150 mm (Ester Hutchinson, MCAGCC biologist, personal communication, 1993). This is a phenomenal growth rate, and additionally, the tortoise possesses the morphological characteristics of a male, with the exception of an indented plastron. However, the tortoise's carapace scutes* are distorted, apparently due to the hight growth rate, but the effects of diet cannot be ruled out. Additionally, the tortoise displays retarded motor skills and coordination, which are particularly evident during feeding. Therefore, in at least some aspects of neurological function, the almost subadult tortoise parallels juvenile behavior. Table 1 gives the maturity classification of Desert Tortoises on the basis of maximum carapace length.

The lifespan of a Desert Tortoise is estimated to be 100 years (Hohman et al. 1980). Senescence or loss of reproductive output is not known, but probably is similar in wild and captive tortoises. Although young tortoises possess annual growth rings on their scutes, these may not be a reliable age indicator because the rings may be incomplete

* scutes: horny dermal plates characterizing the carapace (upper shell) and plastron (lower shell).

or may fuse together. In larger tortoises annual growth is not discernible, and wear on the scutes is appreciable in older tortoises.

Table 1. Maturity classes of the Desert Tortoise based on maximum carapace length.

Maturity Class	Maximum Carapace Length (mm)
Hatchling	36-50
Juvenile	
J1	< 60
J2	60 - < 100
Immature	
I1	100 - < 140
I2	140 - < 180
Subadult	180 - < 207
Adult	
A1	207 - < 240
A2	>/ = 240

(Peter Woodman, tortoise biologist, 1989, personal communication.)

Species that have high survivorship under natural conditions, a low reproductive rate, and require an appreciable length of time to reach sexual maturity are collectively known as *K-selected* species. The Desert Tortoise is an excellent example of such a species. The terminology is relative and has less theoretical relevance than was once hoped for, but it is useful for broadly classifying and discussing adaptive elements of life-history strategies, and appreciating ecological adaptations. At the opposite end of this scale are *r-selected* species. Most insects and rodents are r-selected species, who balance high mortality with high reproductive output and short generation times. Two opposing life-history strategies can lead to reasonably stable equilibrium population levels. It is not surprising that most endangered and threatened species are characterized as K-selected species, with external factors reducing survivorship or affecting naturally low reproductive rates.

Estivation and Hibernation

Desert Tortoises, like all ectotherms, must use behavioral adaptations to control body temperature. Their activity levels are limited by ambient temperatures. The preferred range of body temperature for active Desert Tortoises has been estimated by many researchers. The values have ranged from 19.0 to 38.3 °C (summarized from Hohman et al. 1980). The primary method Desert Tortoises use to avoid temperature extremes, both high and low, is digging underground burrows. Research on ground squirrel burrows has demonstrated the high degree of environmental moderation that burrows provide (Krzysik 1994b). In the northern part of their range, Beaver Dam Slope, UT, tortoises use different types of burrows for their winter hibernation and summer estivation (Woodbury and Hardy 1948). Summer burrows were usually 1 to 1.5 m long, and located in typical upland desert scrub. Winter burrows or dens were located in the sides of washes where deposits of caliche formed a solid-rock supportive roof for the burrows. The winter dens were from 2.5 to 10 m or more deep, and contained up to 23 tortoises. Winter temperatures in these deep dens remained constant at 13-14 C. Deep winter dens were also found in upland habitats. The ratio

of summer burrows to winter dens in Utah was 4:1. In the southern part of the tortoise's range, (e.g., southern Arizona), burrows are usually just deep enough to shade tortoises (Auffenberg 1969). Bury et al. (1978) reported a lack of wear on tortoise scales and scutes in Mexico, suggesting that burrowing habits were not developed. Luckenbach (1982) reported that both deep and shallow burrows can be found in California's Mojave Desert, including several deep labyrinth Utah types found around Hinkley (near Barstow). Marlow (1974) found that the average depth of burrows near the Desert Tortoise Reserve was 1 m, and burrows longer than 3 m were unusual. At Fort Irwin, tortoises have been found in summer burrows ranging from 20 cm to 2 m in length. Caliche caves and burrows in washes may represent important winter hibernacula for Desert Tortoises in the Central Mojave Desert (A. Krzysik, personal observation).

Physiological Ecology

A critical factor in the adaptation of reptiles and amphibians to desert environments is their tolerance of temporary imbalances in physiological regulation (Shoemaker and Nagy 1977; Minnich 1979a). Two important aspects of this problem for the Desert Tortoise are the conservation of water, which is a scarce and unpredictable resource in the desert, and the excretion of electrolytes (salts), especially potassium. Potassium concentrations are high in many desert plants eaten by the Desert Tortoise (Minnich 1979b, Table 1). The Desert Tortoise lacks a salt gland, and must therefore excrete electrolytes in urine or feces (Minnich 1977). Increasing potassium loads may cause tortoises to stop feeding when insufficient water is available to excrete this electrolyte (Minnich 1977).

Nagy and Medica (1986) have studied the environmental physiology and physiological adaptations of the Desert Tortoise. The following account is summarized from their physiological monitoring of a population in Nevada. Tortoises emerged from hibernation in early spring. They fed on succulent annuals, which increased body water, and excess water was stored in their large urinary bladder. However excess salts, primarily potassium, also become increasingly concentrated in the urine and in the plasma. Therefore, the Desert Tortoise was osmotically stressed by its spring diet. Interestingly, the food energy obtained from these annuals was less than the energy loss to respiratory metabolism and muscle activity, and tortoises lost dry matter weight. In the late spring and early summer as plants dehydrated, tortoises switched to feeding on dry perennial grasses. On this diet tortoises lost body water and mass to respiration, but regained positive energy balance on the dry diet and increased the dry matter content of their bodies. Blood and urine osmotic concentrations remained high but stable. Increasing summer drought decreased above-ground activity by

tortoises, inducing estivation and the cessation of feeding, probably as a response to avoiding the toxic effects of the increasing potassium load. Summer thunderstorms terminated estivation and tortoises became very active, retreating to aboveground pallets instead of burrows. Tortoises liberally drank surface water from natural depressions or self-constructed water catchments (Medica et al. 1980), consuming nearly 20 percent of their body mass. They voided their urinary bladders during this period and increased their body mass by 13 percent. Their urine became very dilute, and their plasma osmotic and ionic concentrations dropped. The tortoises fed actively on dry grass and forbs. In the fall tortoises fed on the succulent green vegetation produced by the summer thunderstorms. Tortoises again were in slightly negative energy balance, and urine and plasma osmotic concentrations increased, but tortoises maintained approximately constant body mass and water content until they entered their winter burrows throughout November. Over the winter, hibernating tortoises possessed very low metabolism, and they lost body water, body dry matter, and body mass at very low rates. They only weighed a little less when they emerged from hibernation the following spring. Desert Tortoises have adapted to periodic and unpredictable water availability by not maintaining daily internal homeostasis, while tolerating large imbalances in their water, energy, and salt budgets. However, on an annual basis, water and salt budgets are balanced and energy gain is positive. During long periods of severe drought, tortoises are physiologically stressed.

Habitat Requirements

The predominant habitats of the Desert Tortoise in the Mojave Desert are the bajadas and valleys of the creosote bush scrub community. Bajadas are ancient coalesced alluvial fans, or the long outwash detrital (alluvium) gentle slopes at the base of mountain ranges. Tortoises can also be found in shadscale or alkali sink (saltbush) scrub communities in basins. Although tortoises are found in Joshua tree woodland, this habitat is not usually important for the Desert Tortoise because this community generally occurs above 900 m in elevation. In the Mojave Desert, tortoises occur infrequently at elevations exceeding 1000 m (Luckenbach 1982). High-elevation records reported by Luckenbach for the Mojave Desert are: two live individuals at 1280 and 2225 m, and burrows at 1158 and 1463 m. There have been attempts to develop habitat models or to quantify predictive habitat relationships for the Desert Tortoise (Weinstein et al. 1987, Weinstein 1989), but these have not been successful.

Desert Tortoises prefer deep sandy-loam soils, which is where they reach their highest densities. However, tortoises can be found on a wide variety of soils, ranging from sandy or fine gravel with a clay content, to gravelly, even rocky flats or slopes. Tortoises may also be found in sandy areas, stabilized sand dunes, or the silty or sandy

soils of saltbush scrub basins. Desert Tortoises are distributed on the landscape in a patchy fashion. Wilson (1989) and Wilson and Stager (1989) have data that suggest Desert Tortoise population densities in Nevada are related to seven soil parameters:

1. available water capacity
2. consistence
3. depth to limiting layer
4. flooding
5. salinity
6. temperature
7. rock fragment content.

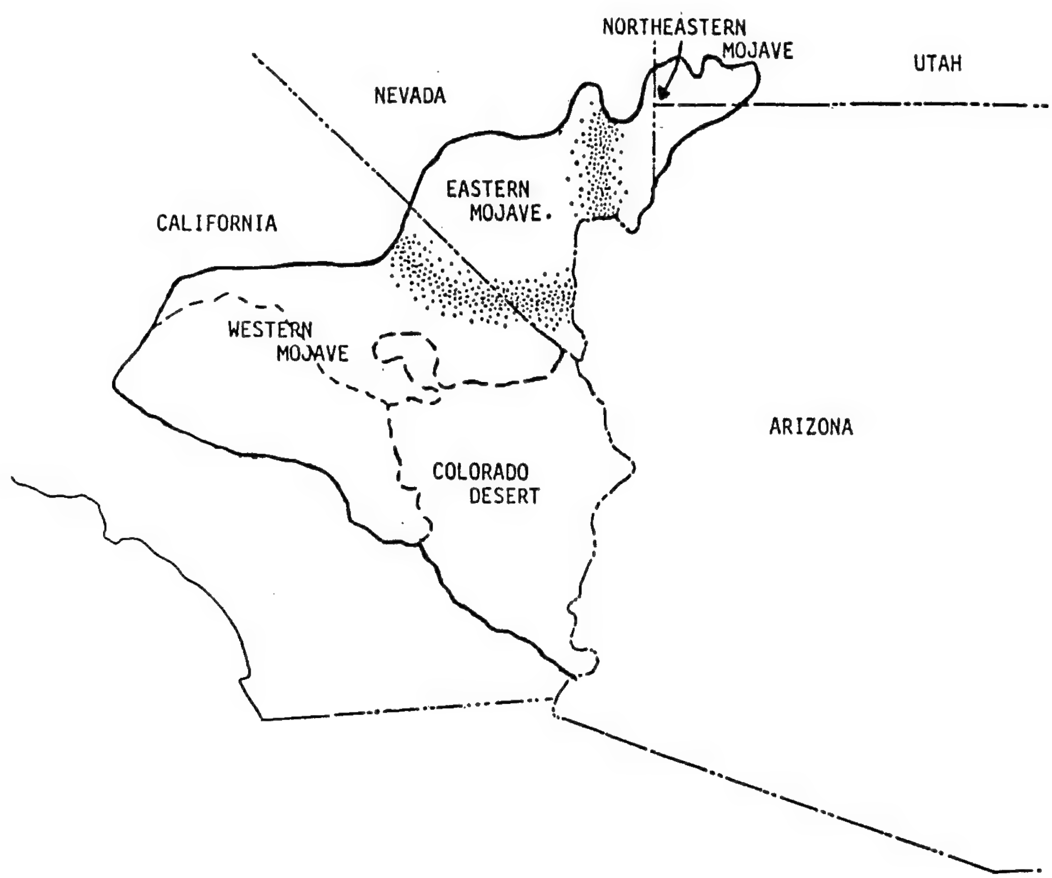
Biogeography

The Desert Tortoise exhibits geographical variation in morphology (Weinstein and Berry 1987), tissue and blood enzymes (Jennings 1985), mitochondrial DNA (Lamb et al. 1989), and allozyme expression (Rainboth et al. 1989). The Colorado River is an important barrier, separating the two major genotypes (currently subspecies), the Mojave and Sonoran. In the Mojave Desert, there may be three genetic races of the Desert Tortoise (summarized in U.S. Fish and Wildlife Service 1990, Figure 4). The Northeast Mojave Group is found in the Beaver Dam Slope area of extreme southwest Utah and adjacent small portions of Arizona and Nevada. Tortoise populations north of St. George, UT (City Creek, Paradise and Snow Canyons) are isolated from—and may be genetically distinct from—the Beaver Dam Slope population (Scott Belfit, BLM tortoise biologist, personal communication, 1993). The Eastern Mojave Group is found west of the above group and occurs across Nevada and into the Ivanpah Valley of California. The Western Mojave Group occurs in the rest of the California Desert (Mojave and Colorado Deserts*), plus the Piute Valley in the extreme southern tip of Nevada. The Western Mojave Group may be further genetically differentiated into three groups:

1. Western Mojave high desert
2. Eastern Mojave (Fenner-Chemehuevi Valleys, Piute Valley)
3. Colorado Desert low desert (Chuckwalla Bench).

The major barrier separating western and eastern Mojave populations is the low sink created by Death Valley. Habitat fragmentation also is promoting the segregation of tortoise populations and metapopulation dynamics. Populations are declining in the

* The Colorado Desert represents the northwest arm of the Sonoran Desert.



Note: Stippled bands indicate approximate borders between the three genetic races.

Figure 4. Three major divisions of Desert Tortoise populations.

Johnson, Lucerne, and Stoddard Valleys in the central portion of the California Desert (Berry 1984). Pockets of Desert Tortoise at Kelso and Shadow Valleys lay between the Western Mojave and Ivanpah-Nevada groups. All of these groups may have been undifferentiated in the past. More research on genetic differentiation and tortoise-habitat modeling will clarify past and present biogeography in this species. The Desert Tortoise population at Fort Irwin is centrally located with respect to California Mojave Desert tortoises, and represents the northeast portion of the Western Mojave high desert group.

Population Trends

There have been serious concerns raised about declining populations of Desert Tortoises, particularly in California. Berry has reported that between the 1920s and

1970s the range of the tortoise decreased from 15,540 sq km to 5960 sq km, and that the present maximum estimate of 250 tortoises per square mile is much lower than populations before the 1920s, which she estimates ranged from 500 to 2600 per square mile (Berry 1984; Berry et al. 1986a; Berry et al. 1986b; Berry et al. 1987; Berry et al. 1988). Most of the evidence for Berry's high estimates was based on interviews with long-term residents, and other anecdotal information. The U.S. Fish and Wildlife Service (1990) has challenged these density estimates, and even the idea of a widespread decline of the Desert Tortoise. The Service reviewed the extensive database and came to the conclusion that historical tortoise density accounts were inflated, and that continued research and monitoring are advisable. However, the Service correctly acknowledged that widespread intensive urbanization and off-road recreational pursuits are damaging Desert Tortoise habitats.

The Service reached three major conclusions about population trends in the Desert Tortoise:

1. Comparisons of present population densities with historical records are weak and unrealistic indicators of population trends
2. Density estimates, sampling procedures (especially unequal sampling efforts), and interpretation of earlier studies may provide an unreliable basis for assessing population trends
3. Declines in tortoise populations were more apparent in juveniles.

There was a relationship between summer precipitation (April-October) and the number of juvenile tortoises located on study plots. Rainfall was unusually high in 1983, but decreased through the 1980s, culminating with the severe drought of 1989. This prolonged drought may have dramatically affected the activity and the survival of juvenile tortoises. Adult tortoises are more tolerant of drought. Female tortoises reproduce in years of severe drought (as discussed under "Reproduction " earlier in this chapter). The final conclusion reached by the Fish and Wildlife Service was that although in some parts of their range (western Mojave Desert and the Las Vegas area) Desert Tortoise populations are declining as a direct result of urbanization and human encroachment, there is no evidence to support the idea of a major reduction in Desert Tortoises densities throughout their range.

Recent surveys continue to show declines in Desert Tortoise Populations, especially in the western Mojave Desert (Berry et al. 1989; Berry et al. 1990; Knowles et al. 1990; Avery and Berry 1991; Berry 1991, 1992).

4 Environmental Stressors

Urbanization

Urbanization is the primary threat to the Desert Tortoise (Luckenbach 1982; Berry 1992). Berry and Nicholson (1984) estimated that in 1975 the human population in the western Mojave Desert was 183,205. At the present, about 731,141 people may live within the range of the tortoise in California (Biosystems Analysis Inc. 1990). Biosystems Analysis Inc. (1990) estimates that 1.3 to 13.2 percent of California tortoise habitat has been lost to urbanization, and they believed that their estimate was too low. One may argue how various specific impacts degrade the habitat for Desert Tortoises, but no one questions the effect of complete and permanent removal of habitats. Extensive urbanization activities, including agricultural conversions, are underway in many regions of the western and southwestern Mojave Desert: Lancaster, Palmdale, Rosamond, California City, Mojave, and Victorville-Apple Valley-Hesperia. Most of the agricultural development is for growing alfalfa—economically a low-cash crop—to feed horses accompanying urban expansion in the desert.

Urbanization effectively improves access for off-road vehicles and increases all types of desert recreational opportunities. Urbanization also includes waste facilities, landfills, roads, and utility corridors. Tortoise populations may be reduced along a corridor running 0.5 km along each side of well used roads (Nicholson 1978). Tortoises have been shot by vandals (Berry 1986a), and urbanization also presents the opportunity to capture tortoises for pets.

Off-Road Vehicles

The use of off-road vehicles (ORVs), also called off-highway vehicles (OHVs), in the California Desert is one of the most controversial issues in southern California. ORVs and related recreation currently represent an important political challenge for both Federal and State natural resources managers (Webb and Wilshire 1983). There are more ORVs in the Mojave Desert than anywhere else in the world (U.S. Fish and Wildlife Service 1990). Recreational use of the desert has increased from 5 million visitor-use-days in 1967 to 15 million in 1980 (Biosystems Analysis, Inc. 1990). Detrimental impacts of ORVs to vertebrates, vegetation, and soils has been reported

(Busack and Bury 1974; Wilshire and Nakata 1976; Bury et al. 1977; Luckenbach 1978; Andrews and Nowak 1980; Adams et al. 1982; Luckenbach and Bury 1983; Webb and Wilshire 1983; Krzysik 1984, 1985; Prose 1985, 1986; Prose and Metzger 1985; Prose and Wilshire 1986). However some vertebrates have responded favorably to decreases in shrub cover, and the sandy loose soils created by military tactical vehicles (Krzysik 1984, 1985, 1994a).

ORVs decrease shrub cover, disrupt desert pavement and soil layers, compact soils, and create dust, noise, and vibrations. Shrub cover loss for tortoises translates to fewer sites for burrows and pallets, reduced shade, and greater visibility to predators. Soil compaction, and possibly also soil disturbance, reduces burrowing potential. ORVs may destroy annuals directly or indirectly through soil compaction, but soils disturbed by tracked vehicle activity—unless compacted— generally display extensive blooms of winter annuals whenever precipitation is adequate (A. Krzysik, personal observation).

Upper Respiratory Tract Disease (URTD)

Rosskopf (1988), in 20 years of clinical veterinary practice, has observed numerous respiratory infections in captive Desert Tortoises. The first major outbreak of URTD in wild tortoises occurred in the spring of 1988 at the Desert Tortoise Natural Area (DTNA), located in the western Mojave Desert, eastern Kern County (Knowles and Knowles 1989). Symptoms similar to URTD have been observed in other populations earlier than 1988 (Berry and Sloan 1989). In the early 1990s, URTD, or symptoms resembling URTD, has been found in tortoises throughout a large portion of the western Mojave Desert, with approximately 10 to 50 percent of the population displaying visible symptoms at several localaties (Krzysik, personal observation; Peter Woodman, personal communication, 1993). The full extent of the epidemic and its epidemiology are unknown (Berry and Sloan 1989; U.S. Fish and Wildlife Service 1990; K. Berry, personal communication, 1994).

URTD is contagious and fatal in the Desert Tortoise (Rosskopf 1988). Symptoms are obvious, and characterized by nasal discharge, often with mucous bubbling at the nose. The nose can also appear wet or caked with mud. Wheezing is also a common symptom, and can easily be heard even if the tortoise is at the bottom of its burrow. Anorexia and open-mouthed breathing also occur. However, clinical appearance alone is not sufficient to identify tortoises infected with URTD (Jacobson et al. 1992).

Jacobson and Gaskin (1990) and Jacobson et al. (1991) examined 17 clinically ill tortoises, and isolated many microorganisms from their inflamed respiratory tracts.

A bacteria, Pasteurella testudinis, and a Mycoplasma-like organism were isolated in all infected tortoises. Both Pasteurella and Mycoplasma are known to cause chronic respiratory infections in birds and mammals. Mycoplasma is relatively new to science and not well known. It resembles a small bacterium without cell walls. Pasteurella testudinis can often be isolated in healthy tortoises. Jacobson and Gaskin (1990) hypothesized that these two organisms may act synergistically to produce effects more detrimental than if each were acting independently. Recently, Jacobson (Professor, University of Florida, personal communication, 1994) has found evidence that the Mycoplasma is the infectious agent in URTD.

Although URTD is suspected of being a major factor in the decline of the tortoise density at the DTNA, its actual role is unknown. Data at this time are insufficient to quantify the impact of URTD on infected tortoise populations, or the potential harm to uninfected populations (U.S. Fish and Wildlife Service 1990; Desert Tortoise Council 1992).

Recently, high mortality rates have been associated with "shell necrosis" for a population of Desert Tortoises at a BLM study plot in the Chuckwalla Bench area of the Colorado Desert in Riverside County, CA (Berry and Avery 1991; Jacobson 1991). The disease appears as lesions on the outer keratinized surface of the plastron or carapace, and sometimes the epidermal hard-parts of the limbs. The lesions appear irregular, with a white flaky appearance. BLM surveys throughout the Colorado and Mojave deserts have indicated that populations in the southern Colorado and eastern Mojave deserts exhibit higher incidence rates of the disease (Berry and Avery 1991).

Raven Predation

Ravens (Corvus corax) are increasingly being implicated in feeding on hatchling and juvenile tortoises (generally less than 110 mm maximum carapace length) (Berry 1985; Esque and Duncan 1985; Berry et al. 1986a, Woodman and Juarez 1988; BLM 1989a; Farrell 1989). Most of the evidence appears to be the accumulation of juvenile carcasses at raven nests. Woodman and Juarez (1988) reported 190 carcasses at the nest of a pair of ravens. The data suggest that possibly only relatively few ravens concentrate on this food source. Carcasses have also been found beneath raven perch sites, such as transmission towers, fence posts, mine-stake posts, and Joshua trees, and ravens have been observed to kill and feed on juvenile tortoises (reviewed in BLM 1990a).

Farrell (1989) conducted raven surveys in 1988-1989 in the eastern Mojave Desert and compared his data to surveys conducted along identical routes 20 years earlier. He

concluded that the occurrence of ravens increased 350 percent along main roads and 700-875 percent along secondary roads.

BLM (1990a) has estimated that raven populations have increased by as much as 1500 percent since 1968. BLM (Rado 1989, BLM 1990b) has developed a raven-management plan with the cooperation of U.S. Fish and Wildlife Service and California Department of Fish and Game. Other agencies involved include U.S. Department of Agriculture and Department of Defense. Five sites were selected for a pilot study to control ravens by a combination of poisoning with the avicide Starlicide™ and shooting (Rado 1990). One of the chosen sites was the landfill at Marine Corps Air Ground Combat Center, Twentynine Palms, CA. Starlicide™ is a that is relatively specific toxin—highly toxic for starlings, blackbirds, crows, and ravens. In normal doses, it appears to be harmless to most mammals (including humans), but cats may be sensitive. Hawks and sparrows show low vulnerability to Starlicide™, but owls and turkeys are sensitive. Pigeons, doves, and ducks are moderately sensitive (see review in Krzysik 1989). BLM is currently continuing an experimental raven-management program that consists of live-trapping and shooting (Boarman 1992). However, the U.S. Fish and Wildlife Service (1990), after reviewing the Audubon Christmas Bird Counts reports for eight locations in the Mojave Desert between 1979 and 1989, report that there was no significant upward trend in raven populations at these localities.

Ravens are highly opportunistic feeders, and urbanization in the desert undoubtedly has been responsible for raven increases. The presence of humans in the desert has certainly increased the supply of food, water, perching opportunities, and nesting sites for ravens. Perch, nest, and prey- monitoring sites are provided by power transmission lines, fences, water towers, buildings, and other manmade structures. Landfills appear to be important sources of food, especially during the winter. Other refuse sites, poor garbage management, sewage ponds, road kills, and even agriculture provide additional food. Reservoirs and leaking water lines provide extra water all year, and ravens can be observed to use these frequently (A. Krzysik, personal observation). Landfills and agricultural areas were the major concentration sites for ravens in four regions of the California deserts (Mojave and Sonoran) surveyed by Knowles (Knowles and Berry 1990).

After reviewing all the available evidence, the U.S. Fish and Wildlife Service (1990) concluded that it cannot determine the effect of ravens on tortoise populations throughout the Mojave Desert. However, ravens have decreased the number of juveniles in localized areas. When combined with additional mortality factors, raven predation may contribute to local population declines in the Desert Tortoise.

Of potential importance for the Mojave Desert ecosystem—but to the author's knowledge it has not been researched—is the effect that increased raven densities are all having on susceptible prey populations: songbirds (including nestlings and eggs), small mammals, lizards, snakes, and invertebrates. Ravens are known to use these taxa as prey (Camp et al. 1992).

Grazing

Grazing is a highly controversial and emotion-charged issue in the American West (Stenger 1954; Wagner 1978; Fradkin 1979; Ferguson and Ferguson 1983; Wald and Alberswerth 1985, 1989; Wuerthner 1992). It is a critical issue for ecosystem integrity in the Mojave Desert, the driest region in North America. Both sheep and cattle graze in the Mojave. Grazing has occurred in the Mojave Desert for such a long time that pregrazing vegetation conditions and tortoise densities are unknown. Furthermore, there have been few studies in the Mojave Desert on the effects of grazing on vegetation or wildlife. Public belief that livestock management and grazing practices in the American West are based on sound ecological science are tenuous at best (McNaughton 1993). Grazing has been blamed for decreasing tortoise populations (Berry 1978; Coombs 1979; Mortimore and Schneider 1983), but the evidence is not conclusive (U.S. Fish and Wildlife Service 1990). Turner et al. (1981) and Medica et al. (1982) found no significant difference in plant biomass, tortoise weights, or reproduction in grazed and ungrazed study plots in Ivanpah Valley. In a literature review, Resources Concepts, Inc. (1989) found that tortoise population declines paralleled reductions in grazing pressure from sheep, and tortoises even declined in areas where there was no recent grazing. It is known that both sheep and cattle have crushed tortoise burrows, and that these grazers compact the soil. Soil compaction reduces the infiltration of rain water and retards the germination of annual plants. Clearly, research is needed on the impact of sheep and cattle grazing on Desert Tortoise populations.

Habitat Fragmentation

The effect of habitat fragmentation on the Desert Tortoise is unknown, because very little is known about their population genetics, viable population sizes, and dispersal abilities across unfavorable habitats (Dodd 1986). Research is needed on Desert Tortoise metapopulation structure and dynamics. It is probable that habitat fragmentation for Desert Tortoise populations produces many of the same problems it does for other species. Fragmentation reduces the amount of habitat available for tortoises. Therefore, fragmentation reduces total population size. Since tortoises

possess relatively low dispersal abilities, fragmentation reduces or effectively prevents gene flow among demes (local populations), and prevents the recolonization of habitat patches subjected to local extinctions. Reduced gene flow reduces population fitness and increases the probability of local extinctions from inbreeding depression, loss of heterosis (decreased genetic variability), and genetic drift (the fixation of potentially ill-adapted gene complexes [phenotypes]). However, the genetic problems typically associated with small populations may be relaxed for tortoises (Larson et al. 1984; Bury et al. 1988). There are numerous examples of isolated tortoise and turtle populations worldwide apparently maintaining genetic viability despite very low population densities (e.g., 20–50 individuals, or less) (A. Krzysik, personal observation).

Reduced genetic variability also reduces a population's capacity to adapt to changing biological or environmental conditions. Beside genetic problems, isolated populations —especially small ones—are subjected to high extinction rates. The extinction process could be triggered by physical processes, such as drought, flooding, temperature extremes, or wildfire; biological processes, such as predation, competition, parasitism, and disease; or anthropogenic impacts, such as habitat destruction, pollution, or direct killing or collecting of specimens. These processes (with the exception of the last example) may not cause mortality directly, and usually affect food or shelter resources, reproduction, or some combination of these. Small isolated groups are also susceptible to extinction from stochastic (random) fluctuations in population numbers. Although the dynamics of population fluctuations are not completely understood, they have been observed for many species under natural conditions. Extinctions in local populations are undoubtedly a common occurrence in natural ecosystems, particularly in stressful environments such as deserts. However, in undisturbed ecosystems, immigration from other population centers fills the void—sometimes rapidly. The realities of fragmentation and isolation of habitat patches are relative, and are dependent on many factors:

- the nature of the isolation barrier or matrix characteristics (nature of the landscape between patches)
- the ecology and life history specifics of the species (primarily home range mobility, ecological and physiological needs and tolerances, reproductive needs)
- the distances between the fragmented patches
- patch size, patch size relative to local disturbance regimes
- patch density in the landscape
- patch suitability, habitat quality, habitat degradation
- ecotone (transition zone) characteristics.

A harmful effect of fragmentation, not always appreciated, is the creation of edges—ecotones between two different habitats. In the case of the Desert Tortoise, edges are

created by urbanization and all its associated land-use, agricultural conversion, extensive ORV and recreational use, mining, and military training activities. Edges represent a source of additional mortality for Desert Tortoises. Tortoises are a K-selected species, as noted previously, and populations with these characteristics cannot tolerate even small increases in mortality rates. See Krzysik (1994a) for a thorough discussion of habitat fragmentation.

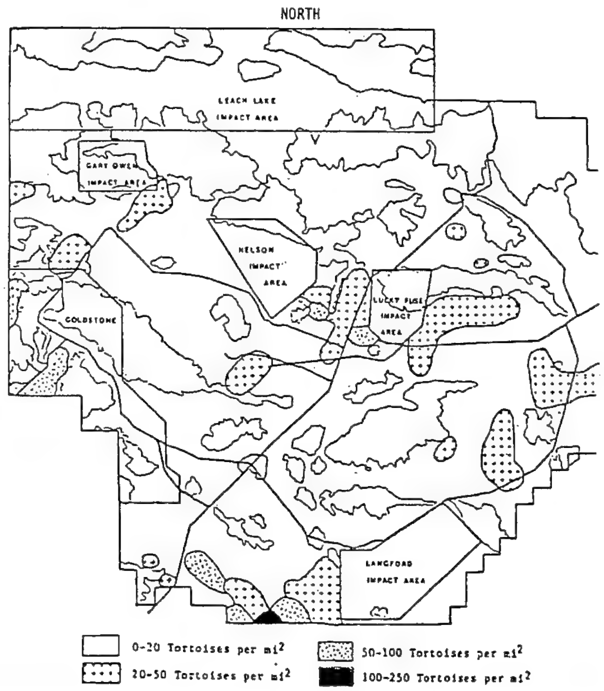
5 Status of the Desert Tortoise at Fort Irwin

Desert Tortoise Surveys at Fort Irwin

The valleys and bajadas of Fort Irwin, south of the Granite Mountains and east of Goldstone, historically contained appropriate habitat for the Desert Tortoise. This species was probably distributed evenly throughout most of the installation, except the mountains, playas, and local areas of unsuitable soils. Tortoises population densities have probably always been low on portions of the installation north of the Granite Mountains, where bajada elevations are 1000 to 1300 m. Relatively few tortoise signs were found north of the Granites in either 1983 or 1989. Desert Tortoises are typically found at elevations below 1000 m in the Mojave Desert (Luckenbach 1982).

During the summer of 1983 a Desert Tortoise survey was conducted on Fort Irwin (Woodman et al. 1986). At this time Fort Irwin had five impact areas—Leach Lake, Langford, Nelson, Lucky Fuse, and Gary Owen—and these were not surveyed because of the hazards of unexploded ordnance. Mountain ranges, playas, and developed areas also were not surveyed. The study located seven populations of the Desert Tortoise on Fort Irwin (Figure 5). The two largest concentrations, both in terms of area of distribution and density, were found along the southern border of Fort Irwin, and on the south bajada of the Granite Mountains. These populations were assumed to have extended into nearby impact zones: Langford in the south, and Lucky Fuse and Nelson along the Granites. The five other populations were already exhibiting fragmentation. Mountain ranges formed natural barriers to dispersal and expansion of the gene pool. Even back in 1983, habitat degradation was extensive in the major valleys from a cumulative total of 35 years of military training activities, and the resulting low cover of perennial vegetation presented a barrier for tortoises. In 1983, Fort Irwin's other populations were located as follows:

1. the far eastern end of the installation, where the southern and central corridors meet
2. the northwestern end of the installation, north and west of Nelson Lake
3. two groups at Goldstone, near Goldstone Lake
4. about 8 km north of the cantonment area, just north of the rise of hills jutting into Goldstone; these hills encircle the north perimeter of the Multipurpose Range Complex, just off the Goldstone Road



Note: Estimated tortoise densities in 1989 were calculated by a different method. See "Survey Methods" in Chapter 5. (Source: Woodman et al. 1986)

Figure 5. 1983 Desert Tortoise populations at Fort Irwin.

5. northeast of Lucky Fuse, just north of the Granites, where there were a few population remnants.

Since the 1983 survey, the four impact zones adjacent to tortoise populations have been cleared of hazardous ordnance. The Langford impact area was cleared and opened in 1984. Lucky Fuse was cleared in 1984-1985. The Nelson impact area was cleared in 1985, and Gary Owen was cleared and opened in 1985 (Tom Clark [NTC Ecologist] and Walt Cassidy [NTC Archeologist], personal communication, 1990).

During the summer and fall of 1989, a Desert Tortoise survey was repeated on Fort Irwin (Krzysik and Woodman 1991). The purpose of the survey was to:

1. establish the current distribution and density of the Desert Tortoise on Fort Irwin
2. compare 1983 and 1989 data to evaluate what effect the establishment of the NTC and its extensive training activities were having on tortoise populations
3. determine the status of the tortoise in the previously unsurveyed impact areas.

Survey Methods

The 1983 and 1989 tortoise surveys were conducted in identical fashion using the standard method adopted by BLM (Berry and Nicholson 1984). The method consisted of looking for tortoise and their sign along 10 yard (9.1 m) wide strip transects. Each transect was 1.5 miles (2.4 km) long, and represented an equilateral triangle 0.5 mile on a side. With experience, and the use of a tally counter, this transect pattern can be replicated with remarkable accuracy. In rugged topography, the use of a Suunto sighting compass ensured accuracy and consistency in conducting surveys with triangular transects. Each transect was assigned a unique sequential identification number, and plotted on Fort Irwin's military topographical maps (scale 1:50,000, series V795S, edition 2-DMA). Two maps cover the installation. A 2cm=1km grid superimposed on the maps makes it possible to rapidly and accurately locate any position on the map using a coordinate system. The use of the UTM coordinate system is explained on the maps. The center of each surveyed transect was assigned a UTM coordinate for future use in geographical and spatial analyses. Effort was taken to place each transect in uniform and representative habitat. The layout of transects on the landscape was systematic, and determined by habitat suitability and the goal of sampling as much of Fort Irwin as possible within resource and time constraints. Areas of unsuitable habitat for the Desert Tortoise not surveyed included mountainous terrain, playas, developed areas, and areas so severely degraded by training activities that vegetation was almost completely absent and soil compaction was evident. Although many transects were surveyed in heavily degraded training areas, badly damaged areas were so apparent upon visual inspection that only minimal sampling was necessary. Leach Lake, an Air Force bombing range that is off limits, was not surveyed.

All tortoise sign observed within each transect band was recorded and consisted of:

- live tortoises—sex, size, condition, location (burrow, open, under shrub)
- tortoise carcasses—sex, size, cause of death, estimated carcass age
- bone or scute fragments
- burrows—width, height, length, condition
- pallets—width, height, length, condition
- tortoise scats—size (width), estimated age
- egg shell fragments
- tortoise tracks
- tortoise courtship rings
- tortoise rain catchment depressions.

Surveys are conducted during the summer, and sometimes in the fall, since maximum tortoise sign is available after their peak of activity in the spring. The sum total of all tortoise sign recorded for a single transect is referred to as *total sign*. For each transect, total sign was converted to *adjusted sign*. Adjusted tortoise sign represents unambiguous and independent counts of burrows, pallets, and scats. The presence and, more importantly, the observation of these three signs is independent of weather and time of day. The above-ground activity of tortoises is strongly dependent on weather (especially temperature), time of day, season, and precipitation patterns. Therefore, if active tortoises were counted as sign on a transect, sign count comparisons among transects would be highly biased by inherent variations in the above parameters. Carcasses and bone fragments also represent biased sign, since these can be relocated by predators or humans. Visible impressions of tortoise tracks and courtship rings are dependent on soil type and texture. These signs are also easily obscured by rainfall and wind. The observation of scats and even burrows is not without bias, since soil color, substrate texture, vegetation type and density, litter cover, topography and aspect, and even sun angle affect detectability. Burrows and pallets that were collapsed or deteriorated were not counted as sign. The final criteria for deriving adjusted sign counts was to delete nonindependent signs found within ten paces of one another. For example, regardless of how many scats of the same size and age were found within ten paces, they were counted as a single adjusted sign. Scats had to be of different sizes or ages to be counted as independent events. Large numbers of scats were often associated with a burrow; these were treated as a single adjusted sign. If two or more burrows occurred within ten paces, the adjusted sign was two, since male and female tortoises often use separate burrows during courtship. Table 2 gives further details about sign identification and classification.

Adjusted sign was converted to estimated tortoise density in the following manner. Each tortoise surveyor conducted identical surveys in calibration plots of known tortoise distributions and densities. These were the BLM study plots where an intensive effort was conducted to locate and mark all tortoises and their burrows on the 1 sq mi* plots. The mark-recapture Lincoln index technique gave a reliable estimate of the actual tortoise density on each calibration plot, and detailed locations of tortoises and their burrows were mapped and available for each plot. Surveys of the calibration plots were conducted in the following manner. Six standard tortoise transects were surveyed in each 1 sq mi BLM plot. The triangular transects were centered on the following six compass bearings: north, east, south, west, northwest, and southeast, with an apex of the triangle located at the center of the plot. It was assumed that burrow distribution throughout the plot was directly proportional to local tortoise density. Each of the six survey transects was assumed to directly survey a 0.25 sq mi

* 1 sq mi = 2.590 km^2.

Table 2. Tortoise scat identification and classification.

Age	Condition
Fresh:	Spring to Present - Black, sometimes brown; usually shiny and smooth; few if any cracks; hard outer surface.
Spring:	"Older" appearing than above, possessing characteristic cracking pattern; drier.
1 Year:	Cracking pattern more developed; color changing to white (in some degree); drier than above; surface integrity looser in appearance, more fibrous.
2 Year:	White; only fiber present.
3 Year:	Highly disintegrating and fibrous.
	Estimating Tortoise Size from Scat Size
Tortoise Size	**Scat Diameter (mm)**
Large Adult	>/= 21
Adult	>/= 14
Small Adult or Subadult	>/= 8
Juvenile	< 8

section of the calibration plot. Because the proportion of burrows in the quarter-section was known relative to the entire plot, a direct estimate of the number of tortoises in the quarter-section was available. A linear regression analysis, forced with a zero intercept, with tortoise densities in the 0.25 sq mi sections as the dependent variable versus adjusted tortoise sign counts as the independent variable, produced the desired calibration coefficient. Each BLM plot produced 6 pairs of data points for the regression. Three calibration plots were used to estimate the calibration coefficient. Because the detection of tortoise sign is a function of an individual's experience and observational abilities, it is standard procedure to calculate a calibration or detectability coefficient for each surveyor involved in the project. Experienced tortoise surveyors possess lower coefficients. The estimate of tortoise density for a given survey transect on Fort Irwin was the product of the adjusted sign count for the transect and the calibration coefficient of the individual surveying the transect. This method represents an estimate of tortoise density on a 0.25 sq mi patch of landscape, and note the direct relationship to the survey of the calibration plots.

The 1983 survey effort encompassed 255 transects. This effort was sufficient to establish the general distribution pattern of the tortoise on Fort Irwin, and produced estimates of tortoise abundance. Because tortoise densities were expected to decline since the 1983 survey, and because the cleared impact zones added more land area to the survey, it was felt that at least a 50 percent increase in survey effort, or 383 transects,

was needed for the 1989 survey. Ultimately, 406 transects were surveyed at Fort Irwin and its boundaries during 1989.

The 1983 Desert Tortoise survey at Fort Irwin was conducted between 26 July and 11 August by Peter Woodman (88 transects, calibration coefficient = 12.8), Karen Kirtland (84, 13.7), and Steven Juarez (83, 14.1), covering 255 transects. The calibration plots used to obtain these coefficients were the BLM plots at Kramer (185 tortoises/sq mi) and Fremont Peak (87 tortoises/sq mi). Each plot was surveyed once by each individual, yielding 12 pairs of regression points for each individual.

The 1989 Desert Tortoise survey at Fort Irwin was conducted between 24 July and 5 November by Peter Woodman (235 transects, 12.5), Anthony Krzysik (136, 12.5), and Gilbert Goodlett (tortoise consultant) (35, 18.8), covering 406 transects. The calibration plots used to obtain these coefficients were the BLM plots at Stoddard Valley (178 tortoises/sq mi), Lucerne Valley (151 tortoises/sq mi), and Fremont Peak (32 tortoises/sq mi). Woodman surveyed the calibration plots three times, Krzysik twice, and Goodlett once. An analysis of covariance indicated that Woodman's and Krzysik's estimated calibration coefficients were statistically similar ($P > 0.7$), and both investigators' data were combined in the regression to calculate the calibration coefficient of 12.5.

Distribution and density patterns on Fort Irwin were determined in the following manner. Each tortoise transect surveyed in 1983 and 1989 was plotted on Fort Irwin military topographical maps and assigned an identification number, its corresponding adjusted tortoise sign, and UTM map coordinates. Separate maps were developed for 1983 and 1989. The maps were visually inspected to determine spatial distribution patterns of tortoise populations on the basis of adjusted tortoise sign for each of the survey periods. Through this inspection process, tortoise populations or pockets of tortoise presence were easily identified and delineated by UTM coordinates. The boundaries of these identified populations were natural topographical features that lack tortoise habitat (essentially mountains and playas), developed areas, the boundaries of the installation, and areas where surveyed transects indicate an abrupt change in adjusted tortoise sign or—more typically—the absence of sign. Eight populations were identified in 1989. The spatial areas occupied by these delineated tortoise populations are referred to as *sites* in this report. Estimated tortoise densities in these eight sites were compared to densities estimated in 1983. However, two of the 1989 sites contained portions of off-limits impact zones that could not be surveyed in 1983. Therefore, for equitable comparisons between the two data sets, three additional sites were delineated that excluded the impact area portions. Two sites were identified from 1983 data. Six additional sites were identified to add information to the 6-year

comparison, or to provide further details for a major site. Therefore, a total of 19 sites are considered in this assessment.

Tortoise densities were estimated for each site by using the tortoise density data calculated for each transect. Using all transects located within a given site's boundaries, the mean estimated tortoise density and its standard error was calculated for each site. The method used in this study to estimate tortoise densities in the landscape differs from that used by Woodman et al. (1986), who "eyeballed" pockets of high tortoise sign, then calculated local tortoise densities from these high-count transects. The rationale used in the present study locates larger areas of continuous habitat, whose area can be delineated from adjacent habitat patches that are either unsuitable for tortoises or possess a sharp gradient in tortoise sign counts. This method gives more realistic density estimates over larger portions of the habitat, and it also can be used for statistically valid trend analysis. In localized areas, this technique is expected to yield lower density estimates than the Woodman et al. method, particularly where they reported high densities. However, a comparison of both methodologies for the 1983 data set revealed that they both generated similar results.

The standard method for conducting tortoise surveys innately produces high variability in tortoise sign counts among transects, even those sampling the same population. This is because tortoise sign is very patchy in distribution and infrequently encountered. Tortoise distribution is also very patchy on a landscape scale, both for high- and low-density populations. This high sampling variance, combined with small sample sizes, makes the statistical analysis very conservative. The result is that the null hypothesis is rejected (a statistically significant difference is found) only when very large, obvious differences are found. Sample sizes were particularly small in the 1983 survey. Therefore, when the analysis showed that a significant difference was found between 1983 and 1989 tortoise densities, one could be confident that the difference was realistic. However, when no significant difference was found, and population means differed appreciably, interpretation became tenuous. Additionally, small sample sizes may dramatically underestimate a dependent variable (like density) if the values of the independent variable are based on rare events (e.g., scat counts where tortoise density is low).

It should be emphasized that the present 'accepted' transect method for estimating tortoise densities may dramatically underestimate actual tortoise densities, particularly in areas where populations are lower than 50 tortoises/sq mi.

Site comparisons between 1983 and 1989 were done using analysis of variance (ANOVA). Two independent analyses were conducted, one on the natural log transformed transect estimate of tortoise density, the other on square root transformed

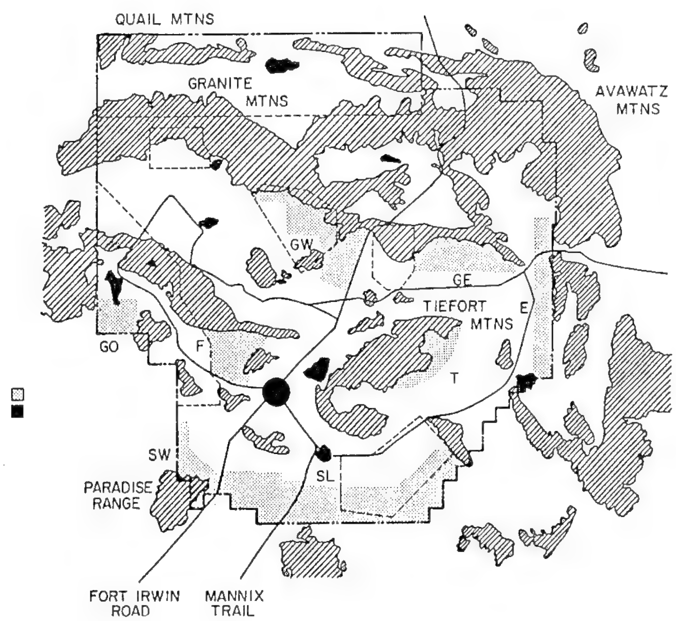
counts of adjusted tortoise sign. The actual transformations used were: TD=Ln(TD+1) and ATS=SQR(ATS+0.5) (Sokal and Rohlf 1969). These transformations were used because the data did not meet parametric assumptions of normality and homoscedasticity (homogeneity of variances), and counts of rare events are Poisson-distributed. Both analyses yielded similar results. The statistics software package SYSTAT, and a companion graphics package, SYGRAPH (Wilkinson 1988), were used for all data analyses and graphical presentations in this assessment.

Status of the Desert Tortoise on Fort Irwin in 1989

Eight populations of the Desert Tortoise were located on Fort Irwin in 1989 (Figure 6). Figure 7 shows the estimated tortoise densities for these sites. Table 3 gives the UTM coordinates for the boundaries of these sites and all the other sites discussed in this assessment. Table 4 gives the size of the sites, estimated mean tortoise densities, and the standard error of the mean. Four of these populations represent isolated gene pools. Extensive loss of woody perennial vegetation, attributed to Army training activities, was the primary cause of the isolation, but isolation was reinforced by mountain ranges.

The most extensive and highest density Desert Tortoise population on Fort Irwin is the SL site. The site is 140 sq km, 4 to 5 km in width, and is located along the southern boundary of the installation between Fort Irwin Road and a volcanic basalt uplift known as The Whale. This population is contiguous with tortoises south, southeast, and southwest of Fort Irwin on BLM lands. The mean tortoise density in this area was 61 tortoises/sq mi. Interestingly, when the SL site was divided into three sections, tortoise density decreased from west to east: between Fort Irwin Road and the Mannix Trail (IM) the density was 90 tortoises/sq mi, between the Mannix Trail and the western boundary of Langford impact area (ML) it was 73/sq mi, and at the Langford area (L) it was 47/sq mi. These data are shown in Figure 8.

Two other populations were located at the perimeter of the installation. The southwestern portion of Fort Irwin contained localized pockets of tortoises. This is the SW site (26.3 sq km), which contained 21 tortoises/sq mi. This population remains in some contact with the large SL population across Fort Irwin Road to the east, and contact with populations in the Superior Valley (BLM lands) occurs through a saddle in the Paradise Range, which lies just southwest of the fort. Good tortoise habitat with a high population density can be found south and west of the Paradise Range (see discussion and Table 11 in Chapter 6 for details). Site E is located along the eastern boundary of Fort Irwin, and is also directly contiguous to tortoises on BLM lands. This



Note: Cross-hatched areas are mountains; dark areas are playas; dashed lines indicate former impact areas and Goldstone.

Figure 6. 1989 Desert Tortoise populations at Fort Irwin.

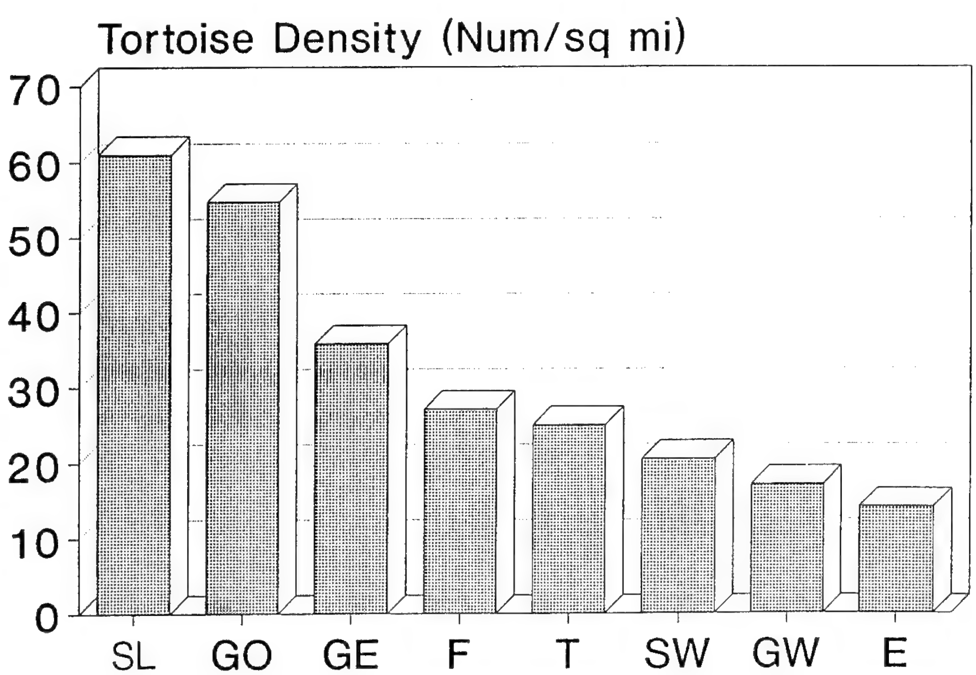


Figure 7. 1989 estimated tortoise densities at Fort Irwin.

Table 3. UTM coordinates of tortoise sites at Fort Irwin.

Site	North	East	South	West
C	Cantonment Area	Langford Road, Langford Dry Lake, Langford Impact; 291010, 337950, 367917	222930, 290930, 290920, 320920, 320910, 367910	Ft. Irwin Road; 277008, 222930
E	210 E	Ft. Irwin Boundary; 620 N	030 E	600 N
F	080 E	270080, 270060, 260060, 260050, 250050, 250022	Goldstone Road; 208035, 250022	Goldstone Boundary; 185080, 208058, 208035
G	Site GW	Minus Nelson Impact Portion		
GE	Granite Mountains	570 N	150 E	450 N
GW	Granite Mountains	Main Road through Granite Pass; 398190, 374127	**Southwest** 260245, 260230, 300230, 300190, 340190, 340140, 374127	
GO	120 E	120 N	Ft. Irwin Boundary; 080 E	Ft. Irwin Boundary; 067 N
GOS	Ft. Irwin Boundary 080 E	120 N	040 E	067 N
GP	348210, 400210	Lucky Fuse Impact Boundary; 400 N	120 E	Nelson Impact Boundary; 320120, 320166, 348189, 348210
IL	Sites	IM + ML		
IM	222930, 290930, 290920, 320920	Mannix Trail; 290868, 321920	Ft. Irwin Boundary	Ft. Irwin Road; 213901, 222930
L	367910, 430910, 470950, 490950, 504933	Ft. Irwin Boundary	Ft. Irwin Boundary	Langford Impact Boundary; 367 N
ML	320920, 320910, 367910	Langford Impact Boundary; 367 N	Ft. Irwin Boundary	Mannix Trail; 290868, 321920
NN	067280, 130280, 130273, 200273, 200290	200290, 245247, 269210	210 E	Ft. Irwin Boundary; 067 N
NS	150 E	310 N	080 E	220 N
SL	222930, 290930, 290920, 320920, 320910, 430910, 470950, 490950, 504933	Ft. Irwin Boundary	Ft. Irwin Boundary	Ft. Irwin Road; 213901, 222930
SW	166980, 180980, 180953, 202930, 222930	Ft. Irwin Road; 213901, 222930	Ft. Irwin Boundary	Ft. Irwin Boundary
T	Tiefort Mountains	**Southeast** 430020, 440020, 470030, 500060, 510090		Tiefort Mountains
V	430132, 450150, 570150, 570200, 600200	600N	Main Road through Southern Corridor; 430990, 567030, 600030	430 N

Notes: N represents northing; E represents easting. Data taken from Fort Irwin military map, 1:50,000, series V795S, Edition 2-DMA.

Table 4. Data summary for all tortoise sites and site subdivisions.

Site	Size (sq km)	Year	Number of Transects	Estimated Mean Tortoise Density (NUM/sq mi)	Standard Error
C	64	1983	14	5.8	2.4
		1989	10	11.3	3.9
E	36	1983	6	9.0	4.5
		1989	8	14.1	6.0
F	28	1983	6	6.6	3.0
		1989	12	27.1	7.2
G	35	1983	8	29.1	10.5
		1989	17	15.4	4.1
GE	34	1983	4	32.0	8.3
		1989	22	35.8	7.5
GW	56	1989	27	17.1	3.8
GO	21	1983	3	44.7	15.7
		1989	8	54.7	13.1
GOS	21	1989	8	50.0	11.1
GP	63	1983	12	26.4	9.4
		1989	20	13.1	3.7
IL	71	1983	20	42.8	10.3
		1989	30	82.9	10.9
IM	45	1983	12	32.4	12.0
		1989	17	90.4	16.7
L	69	1989	46	46.7	6.2
ML	26	1983	8	58.4	18.0
		1989	13	73.1	12.9
NN	119	1983	24	11.9	2.4
		1989	22	2.3	1.3
NS	63	1983	8	11.8	3.9
		1989	10	8.8	3.8
SL	140	1989	76	61.0	6
SW	26	1983	7	13.9	6.2
		1989	11	20.5	8.5
T	21	1983	4	16.3	12.1
		1989	11	25.0	6.3
V	221	1983	39	11.8	2.0
		1989	39	4.5	1.3

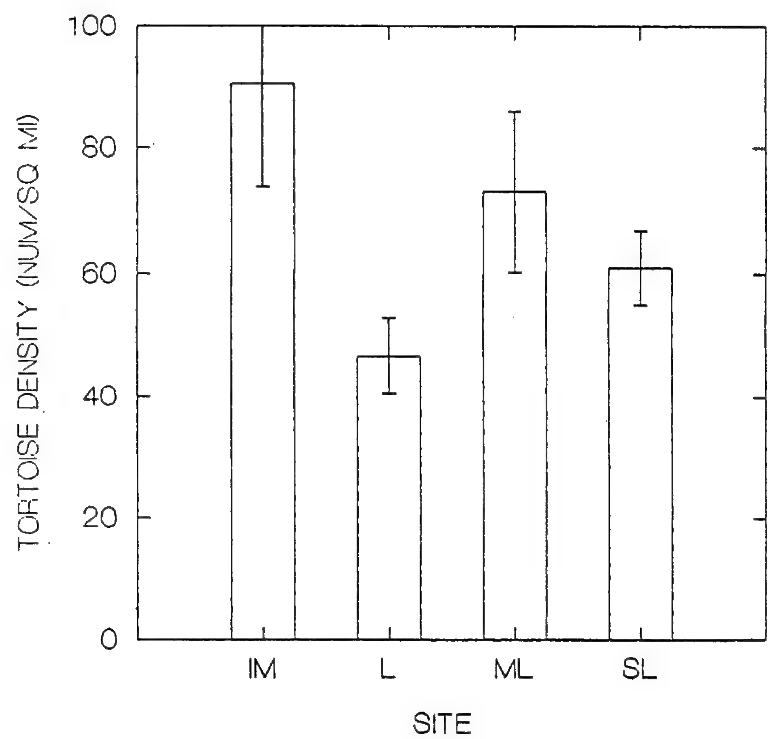


Figure 8. Tortoise population density differentials at Site SL.

site is a band 2 km wide, and 36 sq km in area. Estimated tortoise density was 14 sq mi. Despite extensive surveys, tortoises have not been located east of Fort Irwin on the west side of Interstate 15 (P. Woodman, personal communication, 1992). However, tortoises are maintaining good population densities in the eastern Mojave Desert.

Only one tortoise population was located in Goldstone, site GO, south of Goldstone Lake. The size of this area is 21.2 sq km, and the tortoise density was 55 tortoises/sq mi. The tortoise density on an equal sized area (GOS) directly south of the GO site on adjacent BLM lands was 50/sq mi.

Three isolated populations were located on high bajadas against mountain ranges and encircled by severe habitat degradation. The T site was primarily located in the bowl shaped region at the northeast edge of the Tiefort Mountains. Site T occupies 20.5 sq km and contained 25 tortoises/sq mi. The GE site (34 sq km) is on the south bajada of the Granite Mountains, east of the Lucky Fuse impact area, and extends about 3 km from the Granites. The tortoise density was 36 tortoises/sq mi. Another site (GW) is located on the south bajada of the Granites, west of the main road through Granite

Pass, and into the northern portion of the Nelson impact area. The site is 1 to 3 km wide and occupies 55.5 sq km. Density was calculated at 17 tortoises/sq mi.

Another relatively isolated site (F) is located against the hills that form the northern buffer zone to the Multipurpose Range Complex located off Goldstone Road, just east of Goldstone. Tortoise surveys throughout this live-fire complex indicated that tortoises were present at an estimated density of 27/sq mi. The F site occupies 28 sq km.

Sixty-two live tortoises, carcasses, bone fragments, or scutes were found on the 406 tortoise transects surveyed in 1989 (Table 5). Only three tortoises were seen active on the surface. This is not surprising since the peak of tortoise activity is in the spring, particularly after adequate winter rainfall. Tortoises activity levels are very low in the summer and fall unless there is appreciable precipitation. Both 1988 and 1989 were drought years. Fifteen tortoises were found inactive in their burrows, and 44 carcasses, bone fragments, or scutes were located. The carcasses were of adult or subadult individuals. Under natural conditions, in the absence of URTD, adult and subadult tortoises exhibit low mortality. Seventy percent of the tortoise carcasses were found crushed and disarticulated. Of these crushed carcasses, 74 percent (23 of 31) were found in tank tracks, and one was found on a road. Although this is evidence of direct mortality by tactical vehicles, it cannot be surmised what proportion of these tortoises were alive when they were crushed. Raven predation accounted for 4.5 percent of tortoise mortality. Table 6 gives the estimated age of the 44 carcasses and fragments. Sixty-eight percent of the material was three or more years old. There was no evidence of URTD in Fort Irwin tortoises.

Table 5. Summary of 1989 tortoise sign—live individuals and carcasses.

Desert Tortoise Sign	Number
Active on surface	3
Inactive in burrow	15
(Subtotal)	18
Crushed, disarticulated	7
Crushed in tank tracks	23
Crushed on road	1
Cause of death unknown	5
Bone fragments or scutes	6
Raven predation	2
(Subtotal)	44
TOTAL	**62**

The Air Force bombing range, Leach Lake, was off limits to tortoise surveys because of the hazards of unexploded ordnance. Although mountainous terrain is present at Leach Lake with peaks up to 1459 m, most of the area consists of a central basin and bajadas with elevations between 600 m and 1000 m. There is a good possibility that tortoises occur in the Leach Lake bombing range.

Table 6. Estimated age of tortoise carcasses found in 1989.

	<1 Year	2 Year	3-4 Year	>4 Year	Unknown	Total
Crushed		1	1	4	1	7
Crushed in tank track	2	4	11	6		23
On road			1			1
Cause of death unknown	2	1	1	1		5
Bone fragments or scutes			1	4	1	6
Raven predation	1	1				2
Sum	**5**	**7**	**15**	**15**	**2**	**44**

Distribution and Density Comparisons for 1983 and 1989

Eighty-four rotational training exercises were conducted at the NTC between the 1983 and 1989 tortoise surveys. This training effort consisted of:

- 1265 training days
- 7,595,313 man-days
- 2,080,997 wheeled-vehicle-days
- 681,798 tracked-vehicle-days.

This activity represented 87 percent of all NTC training exercises conducted from the first rotation in 1981 through 1989. The National Guard training effort at the NTC was insignificant, so it was not included in these figures.

Two kinds of 1983–1989 comparisons were of interest. First, the eight tortoise population sites identified in the 1989 data and discussed in the previous section were compared with the 1983 data. Second, tortoise subpopulations identified in the 1983 survey, but not obvious in the 1989 data, were compared. The data for the statistical comparisons between 1983 and 1989 are summarized in Table 7.

Comparison of the Eight Tortoise Sites Identified in 1989

There was no statistical difference in estimated tortoise densities between 1983 and 1989 in five of the eight sites. These are sites: GO, E, SW, GE, and T (Figures 9-13). As a matter of fact, estimated mean tortoise densities were all higher at these sites in 1989. See "Survey Methods" earlier in this chapter, for discussion of the statistical interpretation of tortoise transect data. An additional complication may have been that tortoise scat was more difficult to see in 1983 than 1989. The winter of 1982-1983

Table 7. Statistical significance of comparisons of 1983 and 1989 data.

Site	Number of Transects (1983/1989)	Log Tortoise Density	Square Root Adjusted Tortoise Sign
C	14/10	0.24	0.18
E	6/8	0.83	0.74
F	6/12	0.22	0.10
G	8/17	0.14	0.19
GE	4/22	0.48	0.94
GO	3/8	0.82	0.65
GP	12/20	0.26	0.22
IL	20/30	0.001	0.002
IM	12/17	0.001	0.003
ML	8/13	0.47	0.32
NN	24/22	0.001	<0.001
NS	8/10	0.56	0.63
SW	7/11	0.95	0.64
T	4/11	0.30	0.39
V	39/39	0.006	0.006

Note: The parameters compared were natural log transformed tortoise density [TD=LOG(TD+1)], and square root transformed adjusted tortoise sign [ATS=SQR(ATS+0.5)].

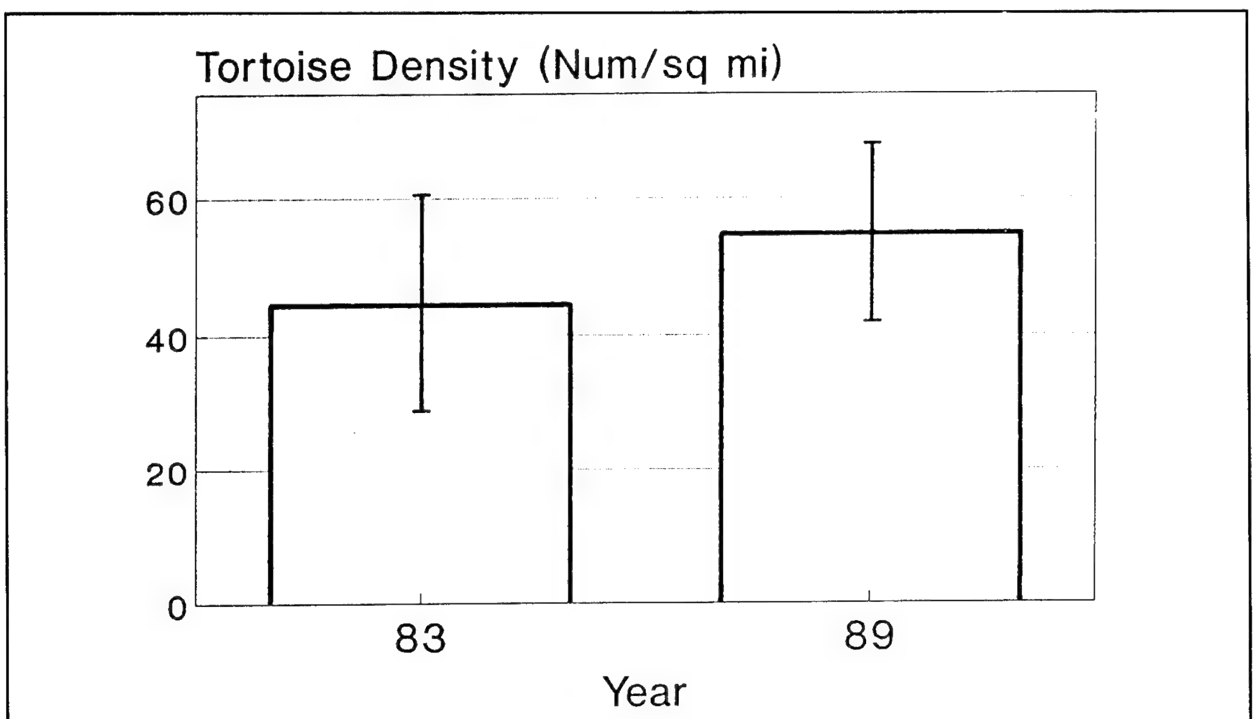
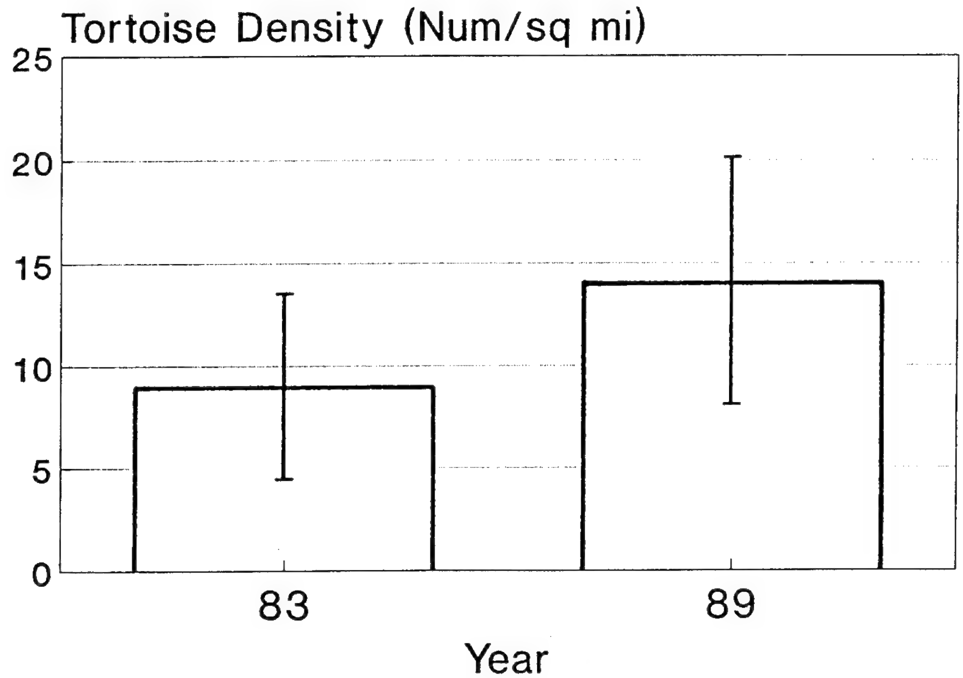
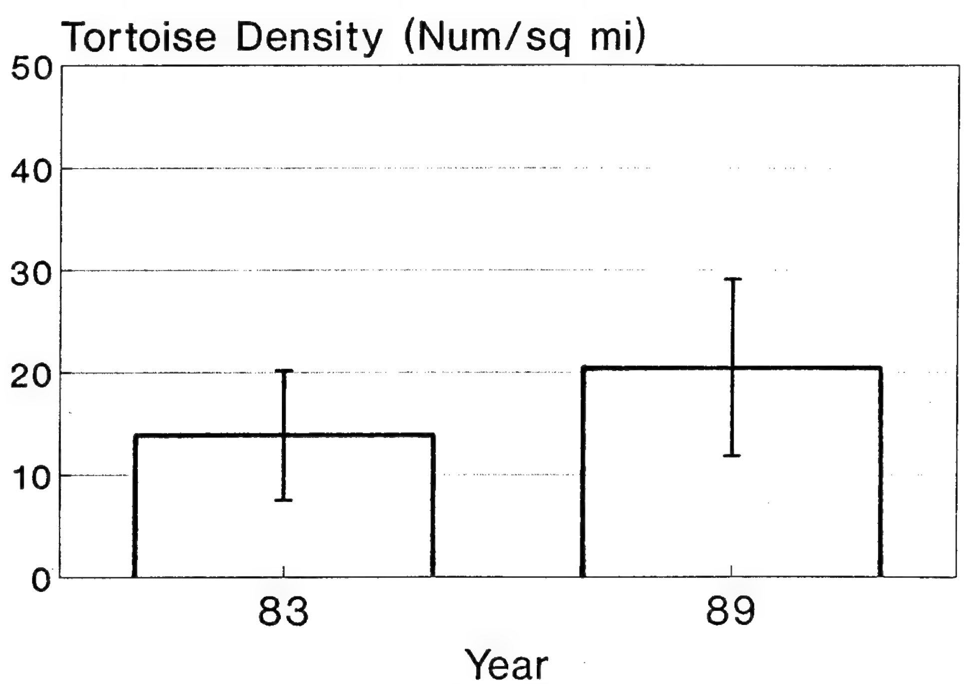


Figure 9. Site GO density comparisons, 1983 and 1989.



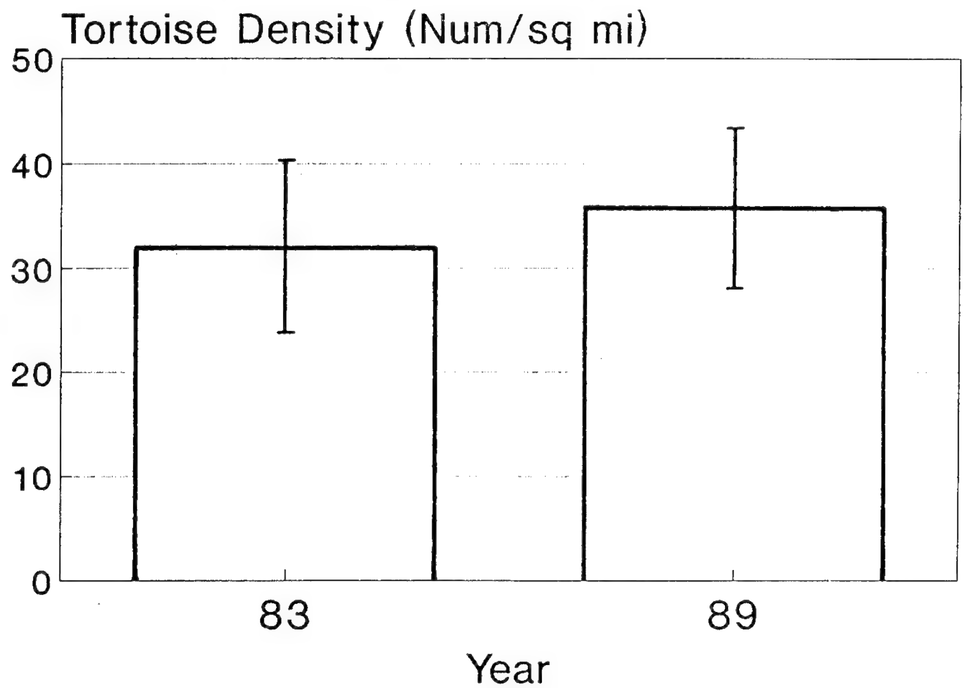
Note: Histograms represent means, and the error bars represent standard error.

Figure 10. Site E density comparisons, 1983 and 1989.



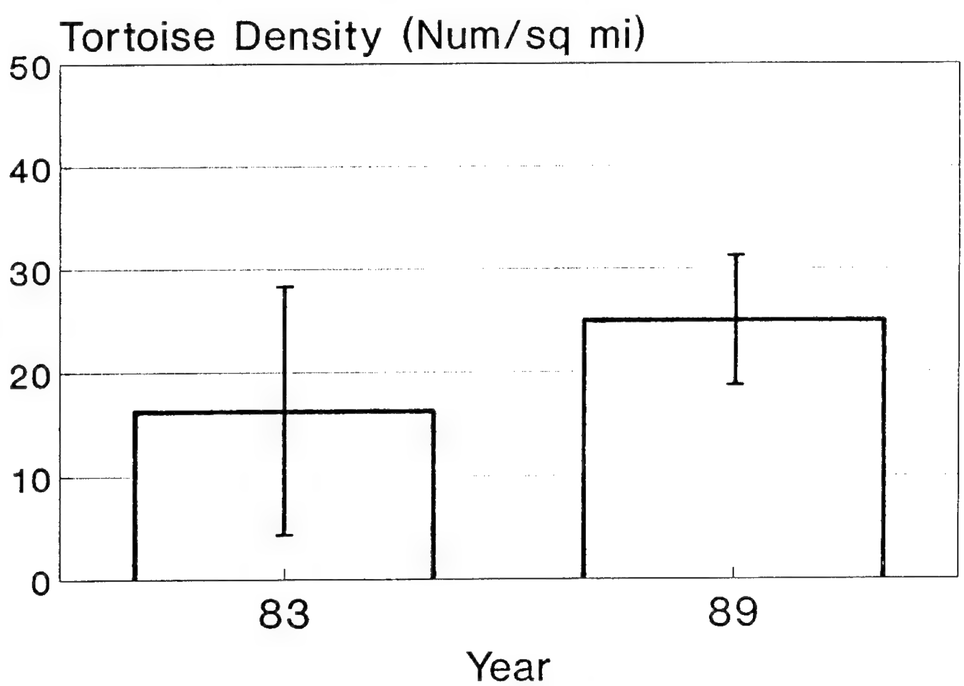
Note: Histograms represent means, and the error bars represent standard error.

Figure 11. Site SW density comparisons, 1983 and 1989.



Note: Histograms represent means, and the error bars represent standard error.

Figure 12. Site GE density comparisons, 1983 and 1989.



Note: Histograms represent means, and the error bars represent standard error.

Figure 13. Site T density comparisons, 1983 and 1989.

was unusually wet, and produced a dense cover of forbs and grasses—particularly annuals. Therefore, during the summer, dry litter was exceptionally dense making scat more difficult to observe. The winter rainfall at Goldstone between December 1982 and March 1983 was 18.3 cm (7.2 in.), compared to the 1966-1984 mean of 7.4 cm (2.9 in.) for this period (Krzysik 1985). The data are interpreted to indicate that tortoise populations remained stable between 1983 and 1989 at these five sites.

The GO site located at the south end of Goldstone Lake, has not experienced any habitat disturbance. Goldstone personnel and their vehicles stay on roads, Goldstone is off limits to NTC tactical vehicles, and public access to the area is denied.

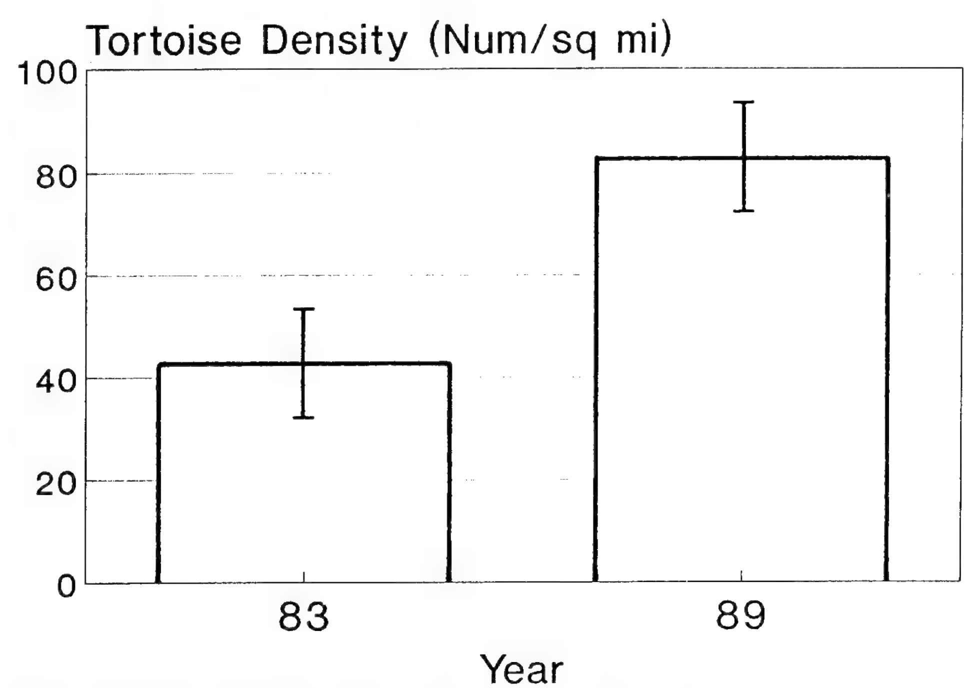
Sites E and SW are along the borders of Fort Irwin, so training impacts in these areas are low. The southwestern corner of the fort is used mainly for helicopter maneuvers. Foot traffic in this area has increased appreciably since about 1987. Tortoises populations in sites E and SW are contiguous with tortoises on adjacent BLM lands.

Sites GE and T are isolated on high bajadas adjacent to mountain ranges. Tactical vehicle impacts are most severe in valleys, and steadily decrease as rugged mountain ranges are approached (Krzysik 1985). High on bajadas deep washes dissect the landscape, making off-road travel slow and difficult. This is particularly true along topographic contours because the steep-banked washes have to be crossed, and tactical vehicles typically use existing roads and trails that bisect the washes. Travel is easiest in the washes themselves, and these channels are used extensively by vehicles maneuvering in this landscape. Therefore, in this rugged terrain, habitat damage by tactical vehicles is less than expected with respect to the number of vehicles that use the area. An important refuge for tortoises on these bajadas are the numerous caliche burrows that occur in the walls of the washes (Krzysik 1994a). These burrows may be particularly important winter hibernating dens, and they are relatively immune from damage by off-road vehicles. These caliche caves are formed by erosional forces and are usually shallow, but occasionally, with the help of burrowing animals, they form retreats 10 m or more in length. On the Beaver Dam Slope in extreme southwestern Utah, caliche burrows represent important winter hibernacula for Desert Tortoises (Woodbury and Hardy 1948).

Although tortoises have been able to maintain their populations at the relatively rugged GE and T sites, habitat degradation and tactical vehicle use are increasing in these areas because of NTC's desire to simulate longer-range weapon systems in modern battle scenarios. Further use and degradation of these two sites, combined with their isolation (which prevents tortoise immigration), may eventually lead to the extinction of the Desert Tortoise in these localities.

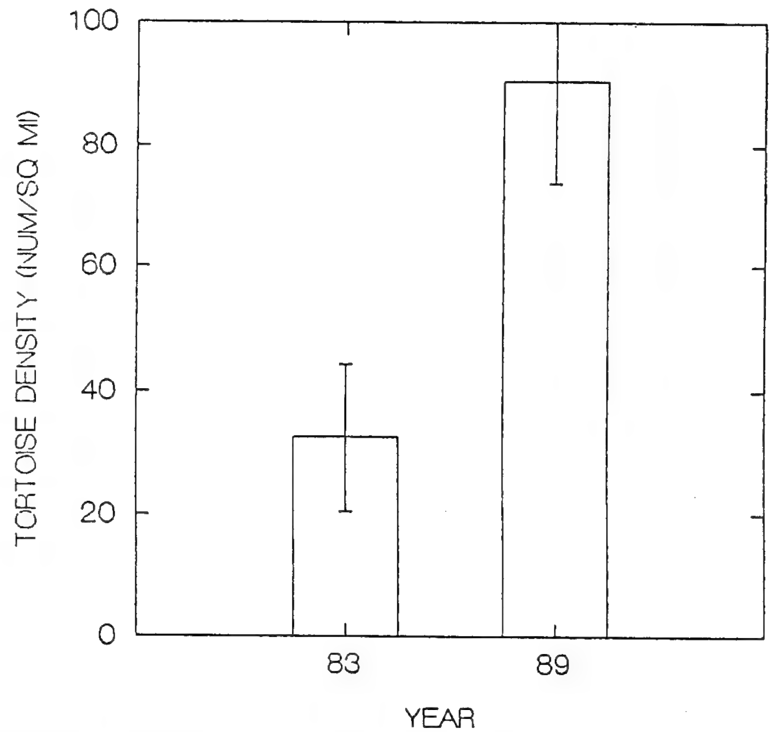
Sites SL and GW cannot be directly compared with 1983 data since they include portions of impact areas, and impact areas were not surveyed in 1983. Therefore, these sites were compared by deleting their impact portions. The SL site with the Langford impact portion deleted, including the southeastern extreme of Fort Irwin, is called site IL. Site IL includes the area from Fort Irwin Road to the Langford impact area, and its northern boundary is the same as site SL. The tortoise density at site IL was estimated to be about twice as high in 1989 (83 tortoises/sq mi) as in 1983 (43 tortoises/sq mi) (Figure 14). Site IL was divided into two sections, IM lying between Fort Irwin Road and the Mannix Trail, and ML lying between Mannix trail and the Langford impact area. At site IM, estimated tortoise densities were almost three times larger in 1989 as in 1983 (90 vs 32) (Figure 15). At site ML, estimated tortoise density was 25 percent higher in 1989 (73 vs 58) (Figure 16), but the difference was not statistically significant (P=0.47).

Habitat degradation and off-road vehicle use have not been extensive in the southern extreme of Fort Irwin, particularly before the Langford impact area was cleared of unexploded ordnance. Only occasional vehicles entered into the Langford impact zone, and these were restricted to the main roads. The southern portion of Langford functioned as a buffer zone for the northern portion, where the live-fire targets were located, and most of the habitat damage occurred. Therefore, minimal ORV damage



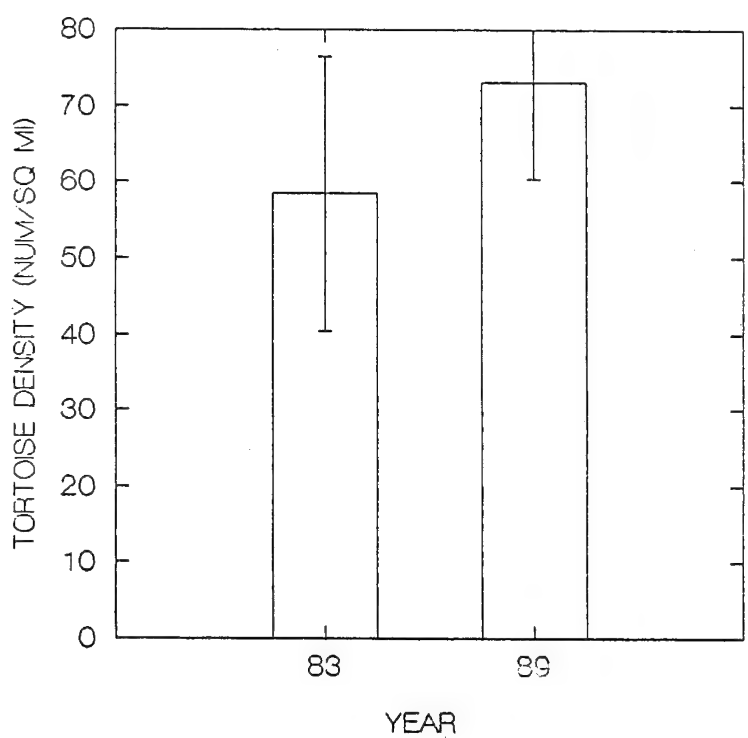
Note: Histograms represent means, and the error bars represent standard error.

Figure 14. Site IL density comparisons, 1983 and 1989.



Note: Histograms represent means, and the error bars represent standard error.

Figure 15. Site IM density comparisons, 1983 and 1989.



Note: Histograms represent means, and the error bars represent standard error.

Figure 16. Site ML density comparisons, 1983 and 1989.

occurred in the southern portion of the Langford impact area. The area west of Langford impact to Fort Irwin Road was mainly used as a staging area, and tactical vehicle use was mainly restricted to roads and trails. Since the Langford impact area was cleared of ordnance in 1984, tactical vehicle use and off-road habitat damage has dramatically increased, not only in the Langford impact area, but also west of Langford, since this area is now a major access route to the previously off-limits impact zone.

The data demonstrate that the Desert Tortoise has increased, or at least remained stable, since 1983 in the southern portion of Fort Irwin. Apparently, moderate and patchy habitat degradation and off-road vehicle use has not yet affected the tortoise at this location. Any of three hypotheses can account for the viability of the tortoise population at site SL.

First, the area has been used extensively only since 1985. With time, further habitat degradation and direct vehicle mortality will eventually seriously impact the SL tortoise population.

Second, this area represents prime habitat for the Desert Tortoise. The topography is predominantly gently rolling bajadas, with deep, sandy loam soils and alluvium. Vegetation is diverse and dense. Perennial shrubs, forbs, grasses, and annuals are all well represented. Galleta grass (Hilaria rigida*) is particularly abundant in some areas. This perennial grass may be the most important summer forage for the Desert Tortoise (Ken Nagy, Professor, University of California at Los Angeles, personal communication, 1990). In such a high quality habitat, it may not be too surprising that the Desert Tortoise could maintain viable populations despite some level of habitat degradation. If habitat quality also directly determines reproductive success in the Desert Tortoise, as it does for other vertebrates, tortoises could maintain viable populations in high quality habitat even when exposure to off-road vehicles resulted in higher than natural mortalities. On the other hand, since the species is an extremist on the continuum of K-selection reproductive strategies, tortoise populations may not be capable of sustaining even low levels of imposed mortality (see “Reproduction” in Chapter 3).

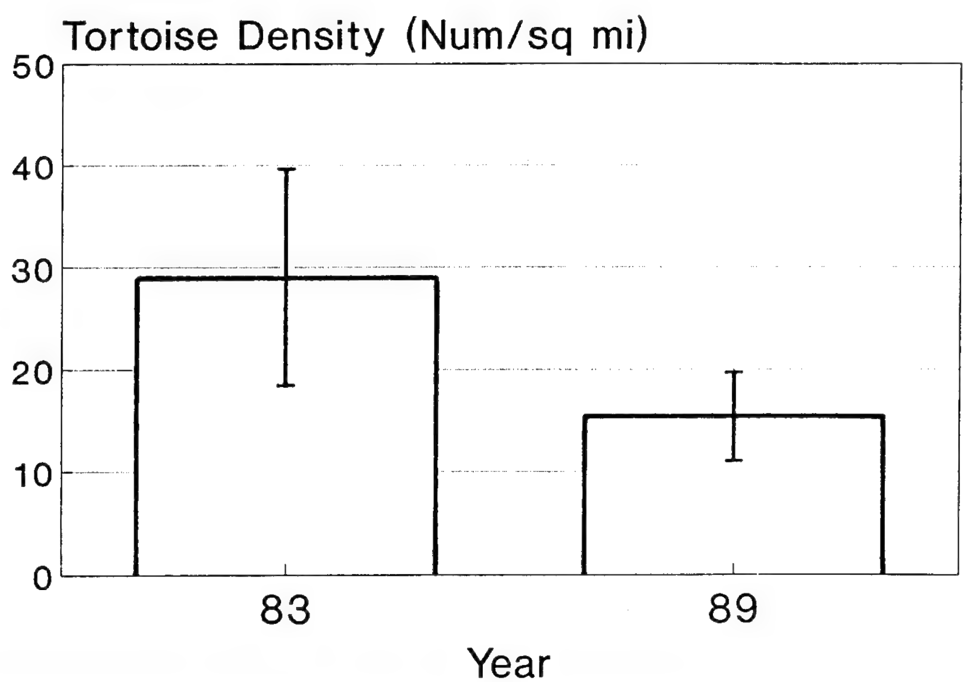
Third, tortoises in the southern portion of Fort Irwin are directly contiguous with populations on adjacent BLM lands. Tortoise densities on adjacent BLM lands are high, with estimates exceeding 200 tortoises/sq mi in some areas (U.S. Fish and Wildlife Service 1988). Undoubtedly, tortoises migrate in both directions over the installation’s boundary. For a limited time, excessive mortality within Fort Irwin could be partially offset by immigrations from the south. However, when the habitat

* now scientifically designated as Pleuraphis rigida after Hickman (1993).

becomes severely degraded and vegetation becomes sparse, tortoises would cease to migrate north into Fort Irwin.

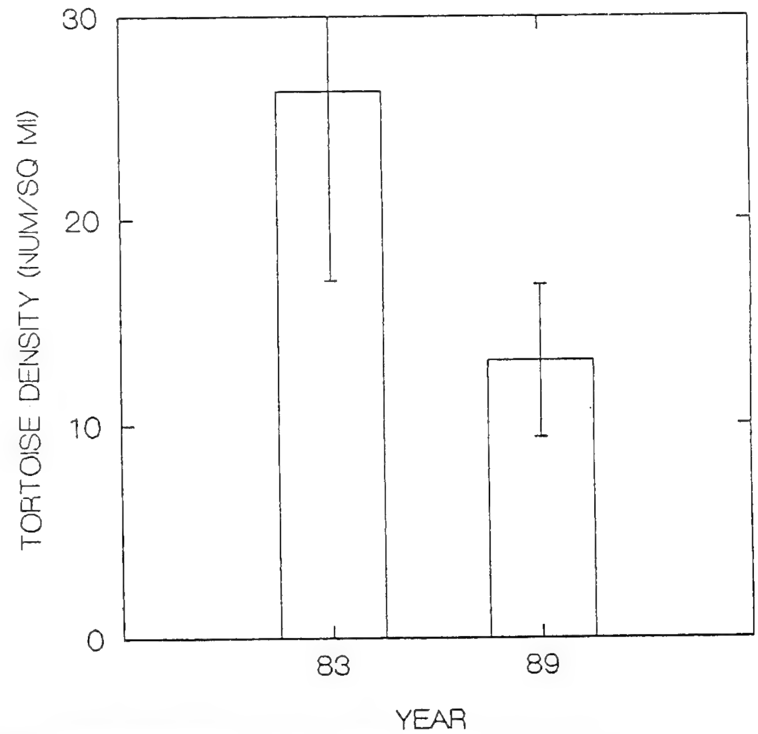
Tortoise habitat on the south bajada of the Granite Mountains was much more extensive in 1983 than it was in 1989. Tortoises extended farther down the bajada, and the population was continuous from the GE site westward into the Nelson impact area. The GW site (17 tortoises/sq mi) is located in the Granite Pass area and extends westward into the Nelson impact zone. Deleting the Nelson impact portion, the site is designated as G. Estimated tortoise density at the G site was almost twice as high in 1983 as in 1989 (29 vs 15) (Figure 17). Site GP was also compared between 1983 and 1989. The GP site is site G with the addition of an area south of Granite Pass. As in site G, site GP had a tortoise density twice as high in 1983 as 1989 (26 vs 13) (Figure 18). However, the statistical significance was borderline in both of these contrasts (see "Survey Methods" earlier in this chapter).

In 1983, sites G, GP, and GE possessed statistically similar tortoise densities (29, 26, and 32 respectively), and the fragmented populations documented in 1989 at sites GW and GE were presumably continuous through the Lucky Fuse impact area. As discussed above, tortoise densities were similar at site GE in 1983 and 1989.



Note: Histograms represent means, and the error bars represent standard error.

Figure 17. Site G density comparisons, 1983 and 1989.



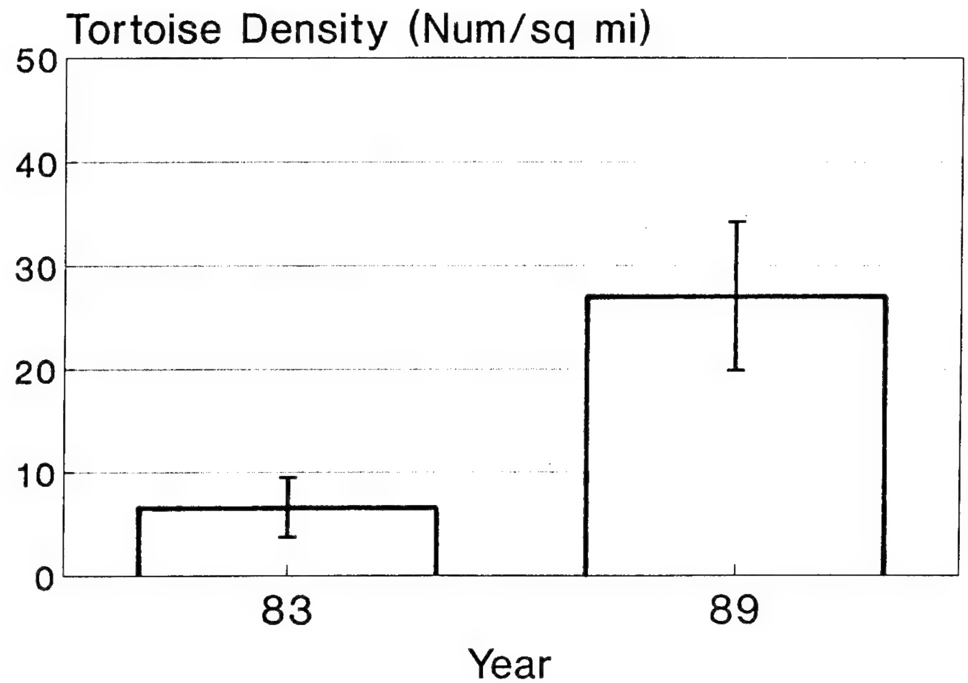
Note: Histograms represent means, and the error bars represent standard error.

Figure 18. Site GP density comparisons, 1983 and 1989.

The major road to the northern portion of Fort Irwin and the live-fire ranges crosses the Granites through Granite Pass. The visual degradation of the habitat and serious loss of vegetation in this vicinity has been very evident and appreciable since 1983, but is particularly evident on the southern bajada of the Granites (A. Krzysik, personal observation). This area is part of the central corridor, one of the two major training areas in Fort Irwin. Habitat damage in the Granite Pass area and the adjacent bajada on both sides of the main road is primarily the result of the NTC expanding war-game scenarios, and the clearing of hazardous ordnance from Lucky Fuse to the east, and Nelson to the west. Both of these former impact zones are now being used heavily by tactical vehicles.

Despite the borderline statistical significance, the comparison of 1983 and 1989 data suggest that Desert Tortoise density has declined in this area, possibly to half the 1983 density. This loss can be directly attributed to extensive habitat loss and direct mortality from tactical vehicles.

Tortoise site F is located at the Multipurpose Range Complex, just east of Goldstone. At this site in 1983, six transects had an estimated density of 6.6 tortoises/sq mi., while in 1989, 12 transects had an estimated 27 tortoises/sq mi (Figure 19). Apparent



Note: Histograms represent means, and the error bars represent standard error.

Figure 19. Site F density comparisons, 1983 and 1989.

ly the small sample in the 1983 survey led to underestimating the tortoise density at this site. Similarly, the small sample size resulted in borderline statistical significance. Long before the NTC was organized, this area has served as a live-fire impact zone. Even in 1983, the central portion of the valley showed vegetation losses from ordnance impacts on target sites. The Multipurpose Range Complex was constructed in the mid-1980s and although off-road vehicle impacts have not been extensive, additional habitat degradation is evident from construction activities and the ongoing live-fire range mission. These activities included the construction of target pads and the maintenance roads leading to the pads. The range is heavily used for a variety of live-fire operations: small arms (pistol, rifle, and shotgun), both light and heavy machine guns, grenade launchers, tank and APC cannons, mortars, antitank missiles, and hand grenades. The majority of the large projectiles are not explosive, but represent training proficiency test (TPT) or high-velocity armor-piercing discarding sabot (APDS) rounds. Table 8 summarizes the intense use of this range. At present, despite the live-fire activity, tortoises remain at moderate densities in this site. The lack of off-road vehicles may in part explain the presence of tortoises. Also, the more intensive use of this range has occurred only over the past few years. Firing range activities, noise, and vibration may eventually eliminate the Desert Tortoise from site F. Tortoises have been seen on four different occasions crossing the road at this location,

Table 8. Multipurpose range complex utilization summary, October 1981 to April 1990.

Weapon	Rounds Fired
Pistol (.45 cal, .38 spec., 9 mm)	435,690
Rifle (5.56 mm)	2,633,701
Shotgun (12 ga)	9,028
Light Machine Gun (7.62 mm)	2,056,275
Heavy Machine Gun (.50 cal)	570,396
Grenade Launcher (40 mm)	305,686
APC Cannon (25 mm)	232,188
M1 Tank Cannon (105 mm)	36,655
Other Tank Cannon (35 mm, 90 mm)	3,909
Antitank Missiles and Rockets (66 mm, 80 mm, 84 mm)	1,250
Mortar (4.2 in.)	1,822
Hand Grenade	3,447
Small Arms (Pistol, Rifle, Shotgun)	3,078,419
Machine Guns	2,626,671
Grenade Launchers, Missiles, Rockets	306,936
Tank and APC Cannons	272,752
Hand Grenades	3,447
Mortars	1,822

going away from the range complex (A. Krzysik, personal observation). Both civilian and military personnel have also reported tortoises on the road at this site. This may indicate emigration of tortoises from the range complex.

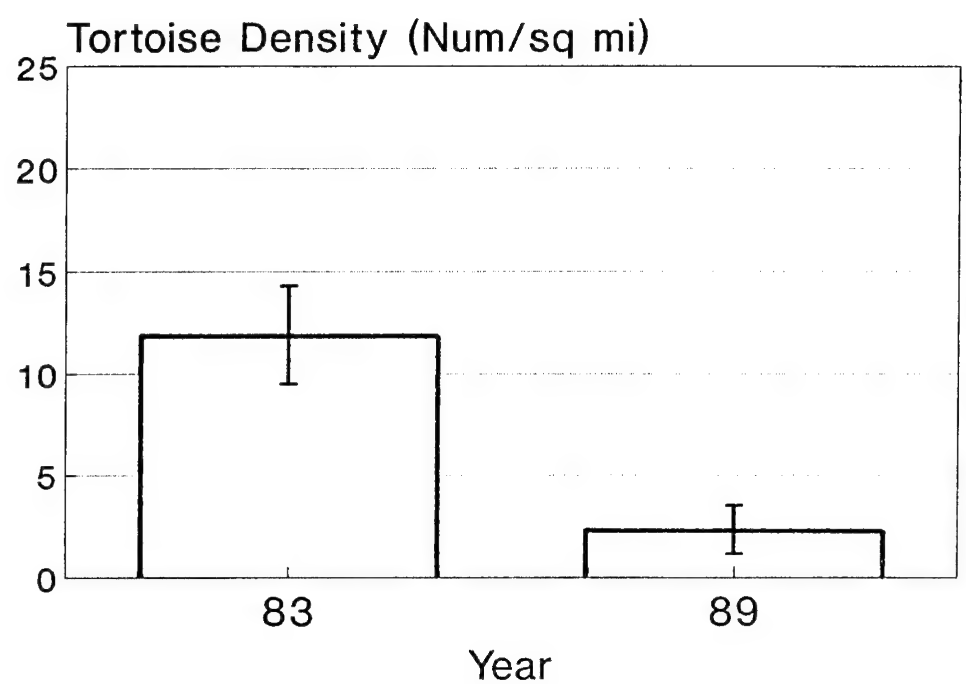
Other Comparisons

In the 1983 survey, four pockets of tortoise populations reported by Woodman et al. (1986) were not obvious in the 1989 analysis (see Figure 5). General localities of these sites are as follows:

1. site NN (119 sq km) in the northwestern portion of Fort Irwin, north and west of Nelson Lake
2. site NS (63 sq km), located 8 km north of the cantonment Area

3. a small population located in the valley just northeast of the Lucky Fuse impact area
4. a small population located 2 km northwest of the northern end of Goldstone Lake.

Tortoise densities dropped significantly at site NN between 1983 and 1989 (12 tortoises/sq mi vs 2.3 tortoises/sq mi: $P < 0.001$) (Figure 20). The habitat in this area was already degraded in 1983. However, the elevations in this region are 950-1200 m, and tortoises occur infrequently in the Mojave Desert at elevations exceeding 1000 m. Woodman et al. (1986) identified three pockets of tortoise populations at densities of 20-50 tortoises/sq mi, in this site. Tortoise sign was absent or scarce on survey transects in the eastern portion of site NN. Because this area is topographically continuous, it was decided to incorporate the entire area as site NN for comparative purposes. Since 1983, habitat degradation has increased, particularly in recent years. Up until at least the early summer of 1986, off-road vehicle traffic in the southwest portion of this area was nonexistent. The few tracks present in this area were probably over 20 years old (A. Krzysik, personal observation). Since 1986, tactical vehicle traffic has increased appreciably, and a staging area was in place by the spring of 1987. Increased use of the northwestern portion of Fort Irwin, particularly around Nelson Lake, has accelerated since 1987. The continued loss of habitat and



Note: Histograms represent means, and the error bars represent standard error.

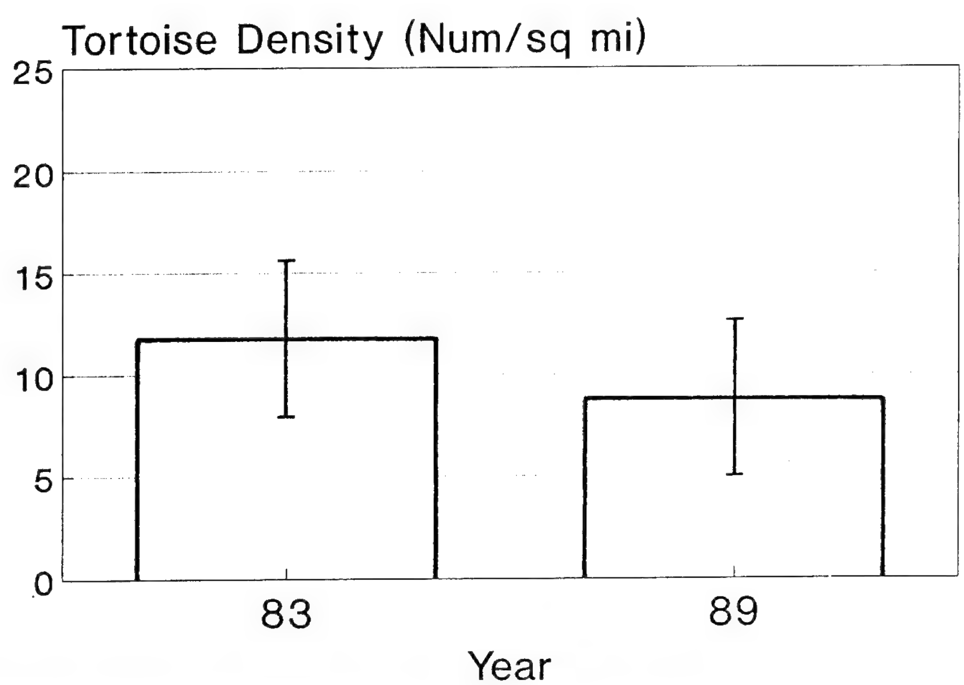
Figure 20. Site NN density comparisons, 1983 and 1989.

increasingly important role of this area in training scenarios ensures the loss of the Desert Tortoise in this area. The loss of this area as tortoise habitat fragments other populations on the installation.

Tortoise densities at site NS did not drop significantly between 1983 and 1989 (12 vs 8.8: P=0.56) (Figure 21). In 1983, tortoise densities were similar at sites NN and NS. This is expected since the areas are topographically contiguous. Habitat degradation in this area has continued since 1983, but not to the same extent as in site NN further to the north. Site NS represents a small, fragmented population surrounded by severe habitat degradation, and a rugged unsuitable hilly terrain to the south. The complete loss of this population is inevitable.

The area between sites NN and SN, and bounded by Goldstone and the Nelson impact area, contained only a few tortoises in 1983 and 1989. The size of this area is 84 sq km. In 1983, 18 transects yielded a single sign, and in 1989, two of 17 transects possessed a total of three sign. This translates to 0.5 tortoises/sq mi—essentially a transient or not-viable remnant population.

In 1983, tortoise sign was found in the valley/bajada north of Lucky Fuse impact and the Granites, indicating a remnant population in this valley. Out of 15 transects in



Note: Histograms represent means, and the error bars represent standard error.

Figure 21. Site NS density comparisons, 1983 and 1989.

this area, two yielded 2 sign each, while a single sign was found on two others. Based on the method used in this assessment, these numbers indicate a density of 5.5 tortoises/sq mi. In 1989, 10 transects in this same area yielded no tortoise sign. Habitat destruction in the valleys and bajadas north of the Granites has been extensive, again particularly over the last few years. Based on the habitat loss in this area, the low tortoise density in 1983, and the lack of sign in the 1989 survey, it can be presumed that the Desert Tortoise is no longer present in the area, or occurs in such a low density that the population is not viable. In a valley/bajada just west of this area, 14 transects in 1983 and 6 in 1989 did not yield any tortoise sign. The valley and bajada habitats in this region are relatively small, gravelly and rocky, and surrounded by rugged mountain ranges. Elevations in these areas are 1000 m or more. Tortoises possibly may never have been abundant in that area. A bajada just southwest of the Avawatz Mountains at an elevation between 900 and 1300 m was surveyed with 11 transects in 1983 and 7 transects in 1989. Tortoise sign was not found in either year.

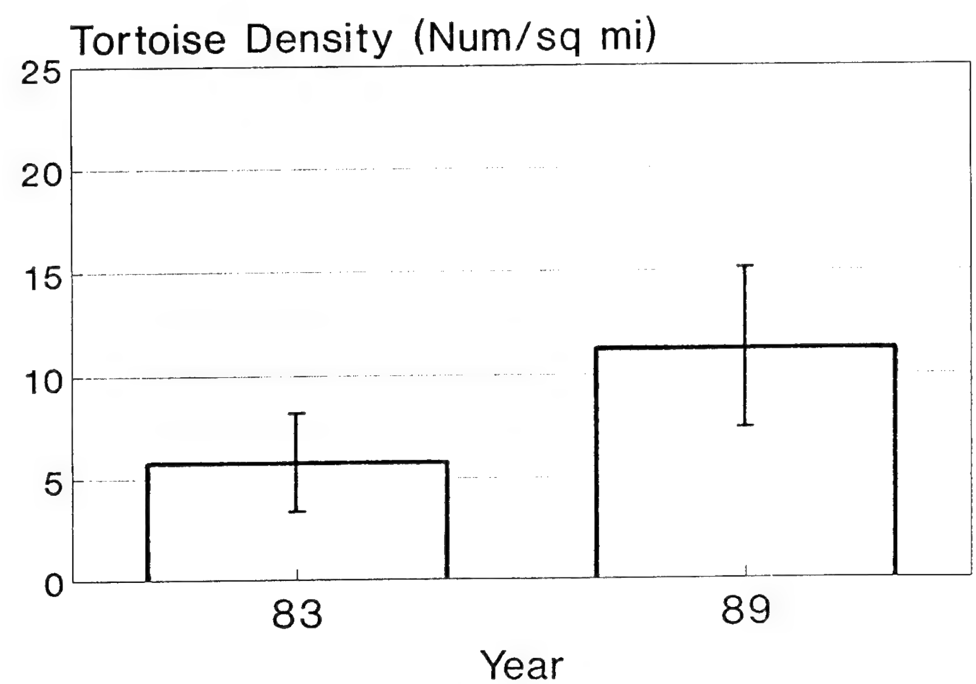
The small valley 2 km northwest of the northern end of Goldstone Lake had an estimated density of 18 tortoises/sq mi in 1983. This estimate was based on only three transects. In 1989, five transects in the same area failed to produce any sign. The habitat has not been degraded since 1983, nor has it changed in any visible way. The small sample sizes make any conclusions tenuous.

The Desert Tortoise is scarce or absent at Goldstone, with the exception of the sites already discussed around Goldstone Lake. However, over a period of 8 years, tortoises have occasionally been seen east of the Echo site near the NTC border (A. Krzysik, T. Clark, personal observations). These individuals probably belong to the F site population located at the Multipurpose Range Complex. Despite the relatively heavy traffic on the main Goldstone road—and therefore the potential for many observations—very few tortoises are seen. Adequate transect sampling in 1983, and especially in 1989, has reaffirmed the unsuitability of Goldstone for tortoises. At least some of the tortoises in Goldstone are released there by Fort Irwin civilian or military personnel (W. Cassidy, personal communication, 1990). The tortoises represent individuals "rescued" from training ranges, as well as those found in the cantonment area. (Cantonment-area tortoises generally represent escaped pets. The ecological/environmental basis for the scarcity of tortoises in Goldstone is unknown, but a combination of several subtle environmental factors may be involved. Goldstone is at an elevation of 900-1000 m or more, even in the valleys and playa basins. Tortoises on Fort Irwin primarily occur below 900 m, and most commonly between 500 to 800 m. The valleys in Goldstone are small and somewhat isolated by rugged granite outcrops or volcanic hills. Therefore, the problems of small, isolated populations discussed earlier come to bear. There is a heavily used "high speed" blacktop road running through the entire length of Goldstone. Tortoise researchers commonly

acknowledge the fact that tortoise populations are generally low within a kilometer or less of major highways, presumably due to vehicle mortality (Berry 1984). The main valley/bajada of Goldstone contains a silty-fine gravel granitic soil. Tortoises never seem to be abundant in this type of soil (P. Woodman and A. Krzysik, personal observations). Other soils in the valley include silty-gravel and silty-volcanic gravel. These are not optimal soils for the Desert Tortoise, which prefers deep sandy-loam soils. However, tortoises can be found in a surprisingly wide variety of soil morphologies (see "Tortoise Habitat Requirements" in Chapter 3).

Two additional tortoise population comparisons between 1983 and 1989 are noteworthy: sites C and V. Site C (64 sq km) represents the area formed by the cantonment area, Fort Irwin Road, Langford Road, Langford Lake, and the SL site discussed earlier in this section. Estimated tortoise densities were low, but higher at this site in 1989 than in 1983 (11 vs 5.8) (Figure 22); the statistical significance of the change was borderline. Despite the proximity of this site to the fort's activity center, tortoises are still present. The viability of site C may be due in part to its proximity to site SL. However, three other factors may also contribute:

1. this site contains rugged outcrops of granite, and tactical vehicles generally use existing roads and trails



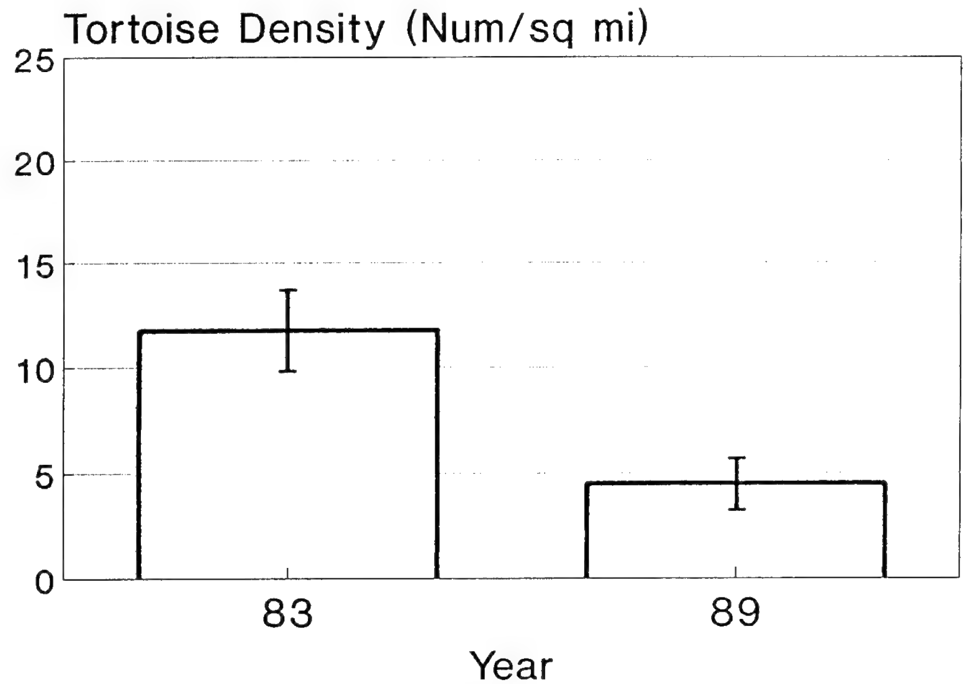
Note: Histograms represent means, and the error bars represent standard error.

Figure 22. Site C density comparisons, 1983 and 1989.

2. major training activities are not conducted at this site because of its proximity to the cantonment area
3. habitat loss and construction activities related to dramatic expansion of the cantonment area since 1985 may have forced resident tortoises to migrate southward—their most feasible escape route containing appropriate habitat.

Site V represents most of the southern and central corridors of Fort Irwin. These are the valleys where most NTC training exercises take place. Site V is 221 sq km, but this does not include the Tiefort Mountains portion within it, because only potential tortoise habitat is considered. Site V is subjected to extensive tactical vehicle traffic and habitat degradation. This site was specifically chosen to study the effect of 6 years of Army training on the Desert Tortoise. The western boundary of V was placed at 430 northing, the eastern boundary at 600 northing (the western boundary of site E). The northern boundary is primarily Lucky Fuse impact and the GE site. The southern boundary is the main road through the southern corridor and Red Pass Lake. The rationale used to delineate the boundaries of V are as follows. Tortoise habitat is poor south of the main road in the southern corridor (three transects produced no sign in 1983, and five produced no sign in 1989). The eastern and northern boundaries of V adjoin other selected sites (E and GE) and Lucky Fuse impact area. The portions of the southern and central corridors west of 430 northing do not contain significant numbers of tortoises. The western portion of the southern corridor is narrow and rocky. Four transects in 1983 and two in 1989 did not produce any tortoise sign. The western portion of the central corridor (northeast of Bicycle Lake and southwest of Lucky Fuse) possesses approximately 2 tortoises/sq mi. Out of eight transects in this area in 1983, one sign each was found on two of the transects. Seven transects were surveyed in 1989, and a single sign was found on one of them. Site T is located within the V site, but neither the area nor the tortoise density of site T is considered in the V site.

At site V, tortoise densities declined significantly between 1983 and 1989: 12 tortoises/sq mi vs 4.5 tortoises/sq mi: (P=0.006) (Figure 23). Habitat quality in both the southern and central corridors was poor in 1983, but deteriorated even more by 1989. Krzysik (1985) conducted floral and faunal ecological surveys in 1983, and quantitatively contrasted the valley floor and bajada portions of the southern corridor with comparable physiography at Goldstone where there were no off-road vehicle impacts or habitat disturbance. These study plots were monitored until 1989. The results are briefly discussed here; a more detailed summary is found in Krzysik (1994a) under "Habitat Monitoring at Fort Irwin."



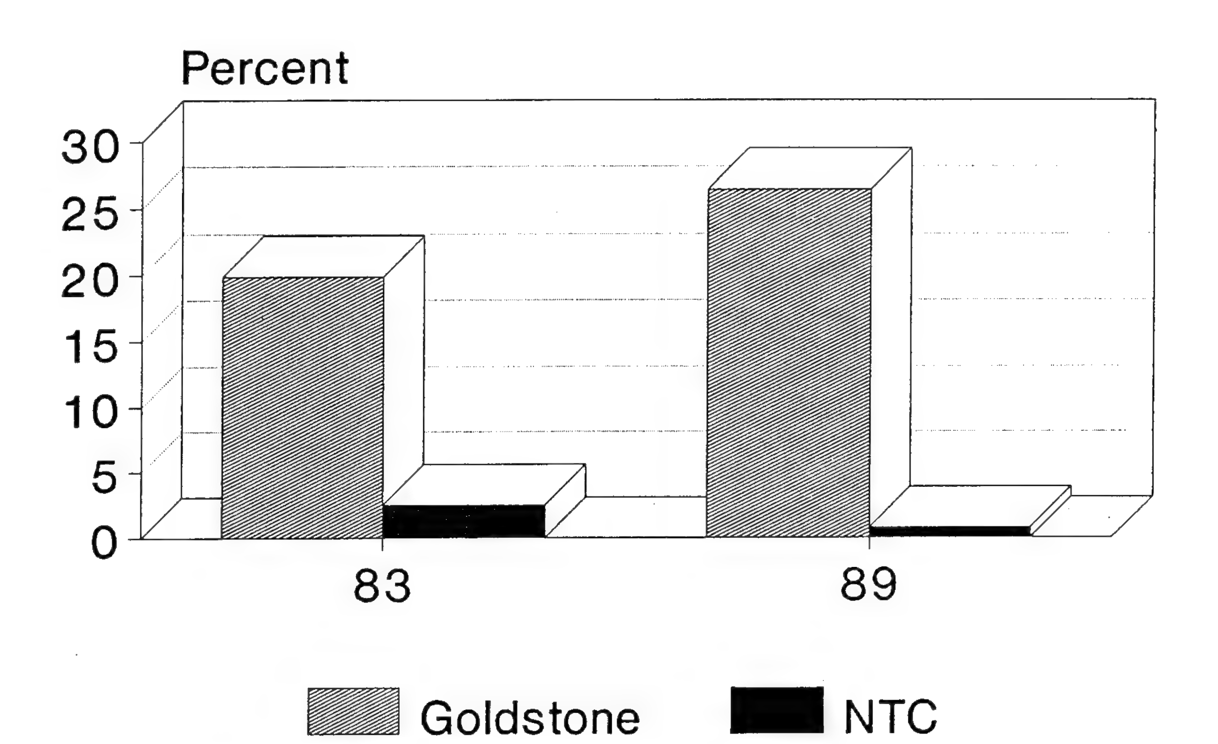
Note: Histograms represent means, and the error bars represent standard error.

Figure 23. Site V density comparisons, 1983 and 1989.

Between 1983 to 1989, shrub cover decreased from 245 m^2/ha* to 76.5 m^2/ha in the valley portion of the southern corridor—a loss of 69 percent (Figure 24). At a comparable valley in Goldstone, shrub cover averaged 2445 m^2/ha over the same time. Between 1983 and 1989, shrub cover decreased on the low bajada from 576 m^2/ha to 189 m^2/ha—a similar loss of 67 percent (Figure 25). Higher up the bajada, the loss between 1984 and 1989 was 1025 m^2/ha to 502 m^2/ha—a 51 percent loss (Figure 25). Shrub cover averaged over this time period 1991 m^2/ha on a similar bajada in Goldstone. On the basis of field experience and qualitative observations, similar losses of perennial vegetation were occurring in the central corridor and other heavily used portions of the installation (A. Krzysik, personal observation).

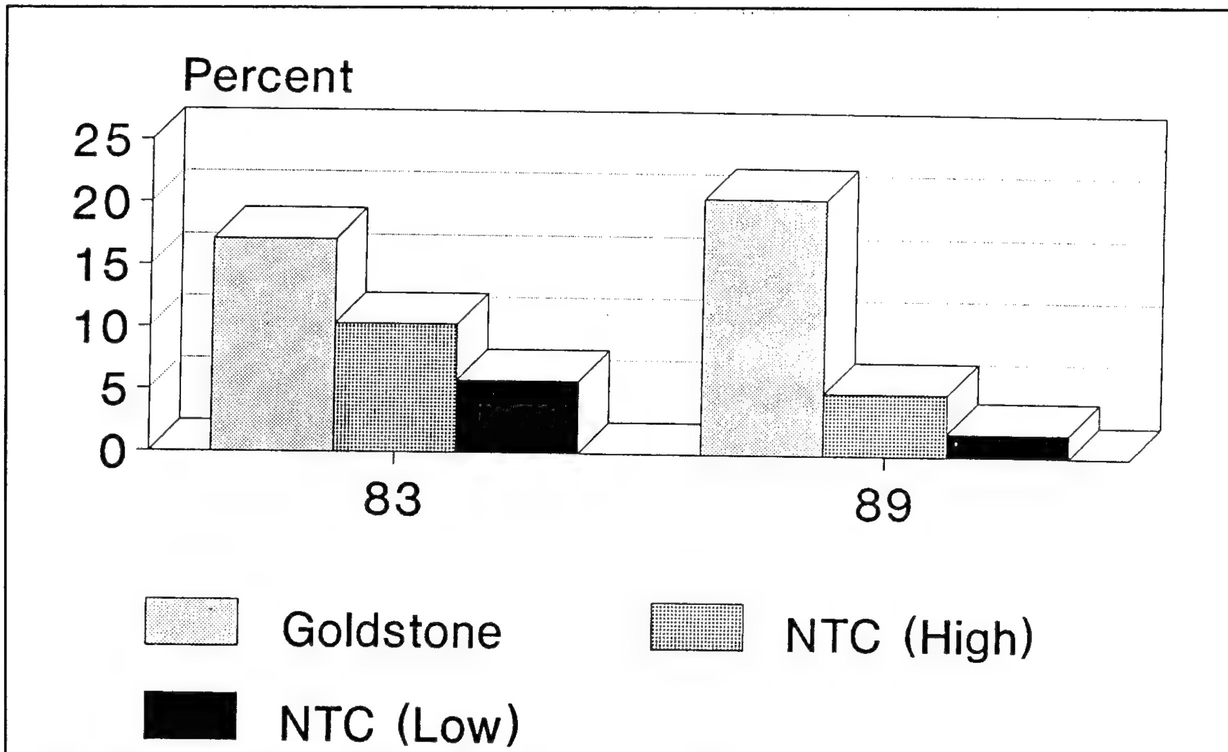
Interestingly, paralleling the loss of shrub cover in the southern corridor, the estimated Desert Tortoise density decreased by 62 percent in the V site between 1983 and 1989. During this same time, in the Granite Pass area of the central corridor (site GP), estimated tortoise density dropped 50 percent. Other density decreases at Fort Irwin were: 81 percent in the northwestern portion of the fort (NN); and 25 percent at NS, located 8 km north of the cantonment area.

* ha: hectare.



Note: Multiplication of the ordinate scale by 100 gives shrub cover in sq m/ha.

Figure 24. Shrub cover comparisons for NTC and Goldstone valleys, 1983 and 1989.



Note: Data for the NTC high bajada were actually collected in 1984.

Figure 25. Shrub cover comparisons for NTC and Goldstone bajadas, 1983 and 1989.

Adequate shrub cover is a critical habitat parameter for the viability of Desert Tortoise populations. Most tortoise burrows are constructed directly beneath shrubs, or in their immediate vicinity. Shrubs provide shade and wind protection, while their roots provide burrow support. Shade is equally important for surface-active tortoises and their thermoregulatory needs. Pallets are important tortoise surface retreats constructed within dense shrubs. Many annual plants are dependent on the presence of shrubs. Checkered fiddlenecks (Amsinckia tessellata), an important forage for tortoises, are more abundant in the vicinity of shrubs than in the open spaces between shrubs. Shrubs also provide cover from predators. Habitat cover is important for juvenile tortoises, because there is evidence that ravens are an important visually oriented predator (see "Raven Predation" in Chapter 4). The shading provided by shrubs may be of crucial importance for the long-term survivorship of Desert Tortoise populations in an unexpected way. While most vertebrates undergo genetic sex determination, most chelonians (turtles and tortoises) undergo temperature-dependent sex determination (TSD), in which the temperature at the nest site determines the sex or sex ratio of the hatchlings (Bull and Vogt 1979; Bull 1980, 1985). Desert Tortoises generally bury their eggs in the floor of their burrows (D. Morafka, personal communication, 1990). In chelonians studied, temperatures above a threshold value produce only female hatchlings, while in some species both high and low temperature thresholds produce females (reviewed in Spotila and Standora 1986). An Old World tortoise was found to have a TSD of 30–31 °C, and Spotila and Standora (1986) hypothesize that the Desert Tortoise also undergoes TSD at a temperature above 30 °C. If the Desert Tortoise does possess TSD, reduced shrub cover would presumably raise the temperature of nest sites and decrease the number of male hatchlings. Unnatural skewed sex ratios are generally detrimental to population viability, particularly in K-selected species.

The decline of Desert Tortoise density at site V, combined with the monitoring of shrub cover in the southern corridor, offers quantitative evidence of the effect that Army off-road maneuvers and the Fort Irwin training mission have on this species. The tortoise will continue to decline at site V. Poor reproductive potential, direct vehicle mortality, and emigration to less degraded habitats will, in approximately 5 years—possibly less—eliminate the tortoise from site V. Occasional vagrants will wander into this area from other adjacent sites where to this point, tortoise populations are more viable: GE, GP (GW), T, and E. However, continued loss of perennial vegetation at site V will make the habitat unsuitable for migrants. Much of site V has already reached this condition.

An important implication for the Desert Tortoise related to the loss of site V (as well as sites NN and NS) is the resulting fragmentation of tortoise populations and their gene pools. These three sites are necessary to make all the other sites within Fort

Irwin continuous with themselves and populations outside of the installation. Habitat fragmentation, including habitat loss and degradation, is the most important factor affecting wildlife populations throughout the world (Myers 1980; National Research Council 1980; Burgess and Sharpe 1981; Noss 1983, 1987; Harris 1984; Wilcox and Murphy 1985; Wilcove et al. 1986; Alverson et al. 1994). Fragmentation reduces genetic variability within populations because gene flow ceases, and isolated gene pools represent only a small fraction of the original one. This may lead to inbreeding depression or genetic drift, including the expression of deleterious recessive genes. However, chelonians appear to be genetically conservative, and may not be as vulnerable to genetic deterioration in small, isolated populations as other taxa (see "Habitat Fragmentation" in Chapter 4 and Krzysik 1994a).

Increasing fragmentation results in smaller and more isolated demes for the Desert Tortoise. These smaller populations are subjected to extinction from natural catastrophies, like weather extremes; human impacts and disturbances, and demographic, environmental, and stochastic (random) biological events.

1989 Survey of Impact Zones

The 1989 Desert Tortoise survey on Fort Irwin included the four impact zones cleared of unexploded ordnance and opened in 1984-1985. These areas were previously off limits to tactical vehicles. Langford was opened in 1984, and Lucky Fuse, Nelson, and Gary Owen were opened in 1985. Therefore, when the 1989 survey was conducted, training vehicles had used the area only for 4 to 5 years. However, because these areas were used to varying degrees since 1940 for tank, artillery, mortar, heavy weapons, and small arms live-fire exercises, habitat destruction was extensive in the vicinity of the targets. Discarded automobiles, jeeps, trucks, tanks, and other Army "scrap" were usually used as targets. Metal fragments and shrapnel from targets, shells, and projectiles profusely litter the ground in the target zone. Also, the noise and vibrations associated with live-fire exercises are detrimental to wildlife populations (Krzysik 1994a). In contrast to the target zone of an impact area, its associated buffer zone contains undisturbed habitat. Shells and projectiles, infrequently land in these areas, and the areas are off limits for training exercises, hunting, and sightseeing. The only traffic these areas are exposed to is occasional maintenance vehicles, which keep to the main roads and trails.

When these impact zones were surveyed in 1989, it was evident that tactical vehicle damage to the buffer zone habitat was relatively recent. Shrub and perennial grass cover was high in most of the buffer zones. Extensive habitat damage only occurred in isolated patches associated with intense local activities. The loss of shrub cover and

habitat damage was extensive in the target zones. The buffer area at Langford, to the south and near the boundary of the installation, consisted of a gentle rise of sandy hills. This area of the Langford impact zone represents half of the SL site, which contains the highest tortoise density located on Fort Irwin. The estimated population density in this buffer portion of Langford (site L) was 47 tortoises/sq mi. The southeastern tip of Fort Irwin is included in site L. The northern portion of Langford is severely degraded, primarily from tactical vehicle traffic, but also from being a live-fire zone. This area is adjacent to the very heavily used southern corridor main road. On both sides of this road the landscape is virtually denuded of vegetation. Tortoise sign rapidly drops off north of the SL site, closely paralleling habitat degradation and the loss of shrubs and perennial grass cover.

The buffer zones for Lucky Fuse, Nelson, and Gary Owen impact areas are in the north where the Granite Mountains form an effective barrier. More than half the area of Lucky Fuse is in the Granites. Eight tortoise transects were surveyed within the bajada portion of this impact area. One transect yielded three sign, and another contained a single sign; both of these transects were in the western portion of Lucky Fuse. Habitat degradation is severe in most of this impact zone. As with Langford, tactical vehicle damage predominates, but target zone damage is also extensive.

The northern-northeastern portion of Nelson impact area represents a portion of the GW site. This site contained 17 tortoises/sq mi. As in the case of site SL, as one goes south or southwest of the GW site, tortoise sign rapidly drops off. Nine transects were surveyed within the Nelson impact area outside of the GW site; two transects yielded three and one sign, respectively. The Nelson and Lucky Fuse impact areas are located in the main central area of Fort Irwin's training activities. Therefore, tactical vehicle impacts are severe, and they will continue.

Four tortoise transects were surveyed within the Gary Owen impact area, and a single sign was found on one transect, at the southeastern tip of the impact area. The elevation at Gary Owen is over 1000 m—higher than optimal to support Desert Tortoise populations.

Total Desert Tortoise Population on Fort Irwin

Table 9 gives the estimated number of tortoises found at each tortoise site, based on the 1989 survey. An estimated range of tortoise numbers, based on the standard error of estimated mean density is also provided. The sum total of Desert Tortoises estimated at all tortoise sites on Fort Irwin in 1989 was 6513 ± 1285 individuals. These tortoises occur on 35 percent of Fort Irwin's landscape. The other 65 percent of

Table 9. Estimated total desert tortoise population at Fort Irwin, 1989.

Site	Size (sq km)	Estimated Tortoise Density (NUM/Sq mi+/-S.E.)	Estimated Number of Tortoises	Estimated Range (based on S.E.)
SL	140	61.0 +/- 6.0	3299	2974 - 3623
GE	34	35.8 +/- 7.5	470	372 - 569
GO	21	54.7 +/- 13.1	444	337 - 550
V	221	4.5 +/- 1.3	384	273 - 495
GW	56	17.1 +/- 3.8	370	288 - 452
F	28	27.1 +/- 7.2	293	215 - 371
C	64	11.3 +/- 3.9	279	183 - 376
NS	63	8.8 +/- 3.8	214	122 - 307
SW	26	20.5 +/- 8.5	206	121 - 291
T	21	25.0 +/- 6.3	203	152 - 254
E	36	14.1 +/- 6.0	196	113 - 279
NN	119	2.3 +/- 1.3	106	46 - 165
Area between NN and NS	84	1-2 (Estimate)	49	32 - 65
Totals	913		**6513**	**5228 - 7797**

the fort either contains unsuitable habitat (mountains, playas, developed areas), or tortoises have been eliminated or reduced to very low numbers—less than one per square mile by habitat destruction and direct mortality.

Site SL represents Fort Irwin's main tortoise population. Not only is it a high-density population that occupies a large area, but it is contiguous with other important populations south of the installation on BLM lands. Other important and dense populations occupying smaller areas include GE, isolated on the south bajada of the granites, and GO at Goldstone. Note that site V, because of its large size, is ranked high in absolute tortoise abundance even though it contains a low density population. Although the Granite Pass population density has declined since 1983, the size of the area makes it an important contributor to Irwin's total population.

Table 10 summarizes the abundance pattern of tortoises on Fort Irwin. Tortoise site SL, occupying 5 percent of Fort Irwin and 15 percent of the landscape supporting tortoises, contained half of all tortoises found on the installation. The eight tortoise sites identified in 1989, occupying 14 percent of Fort Irwin and 40 percent of the fort's habitats supporting tortoises, contain 83 percent of all tortoises found on the

Table 10. Tortoise abundance patterns at Fort Irwin, 1989.

Area of Comparison	Size (sq km)	% of Fort Irwin	% of Tortoise Habitat	Estimated Number of Tortoises	% of Tortoises
Site SL	140	5	15	3299	50
8 Tortoise Sites (see Figure 6)	362	14	40	5481	83
Sites of Declining Tortoise Numbers and Heavy Tactical Vehicle Use	551	21	60	1032	16
All Tortoise Sites	913	35	100	6513	99
Leach Lake Bombing Range	369	14	?	?	?
Unsuitable Tortoise Habitat, Tortoises Eliminated, or Tortoise Density < 1/sq mi	1318	51	---	84*	1
Totals	**2600**	**100**	**100**	**6597**	**100**

* Assumed 33 percent of the 1381 sq km contained 0.5 tortoises/sq mi.

installation. Tortoise populations are declining in the large areas in the fort where tactical vehicle traffic is heavy and habitat degradation is continuing. These areas also may contain vagrants from viable populations. These tortoises are found on 21 percent of Fort Irwin, occupy 60 percent of the landscape supporting tortoises, and represent 16 percent of all tortoises found on the installation. The landscape category of unsuitable tortoise habitats and severely degraded habitats, including Leach Lake Bombing Range, includes 65 percent of the fort's landscape, and contains an estimated 1 percent of Fort Irwin's Desert Tortoise population. The total estimated Desert Tortoise population at Fort Irwin in 1989 was 6597, ± 1285 individuals.

Designation of Critical Habitat

The final rule for determination of Critical Habitat for the Mojave population of the Desert Tortoise was published 8 February 1994, with corrections 24 February (Federal Register 1994). The U.S. Fish and Wildlife Service identified 12 Critical Habitat Units (CHUs) located in the four states inhabited by Desert Tortoises (see "Biogeography" in Chapter 3). The 12 CHUs represent 2,608,741 ha (6,446,200 acres) in the Mojave and Colorado Deserts. Figure 26 illustrates CHU allocation among the states involved, and Figure 27 summarizes the distribution of CHUs by land-use. Note that less than

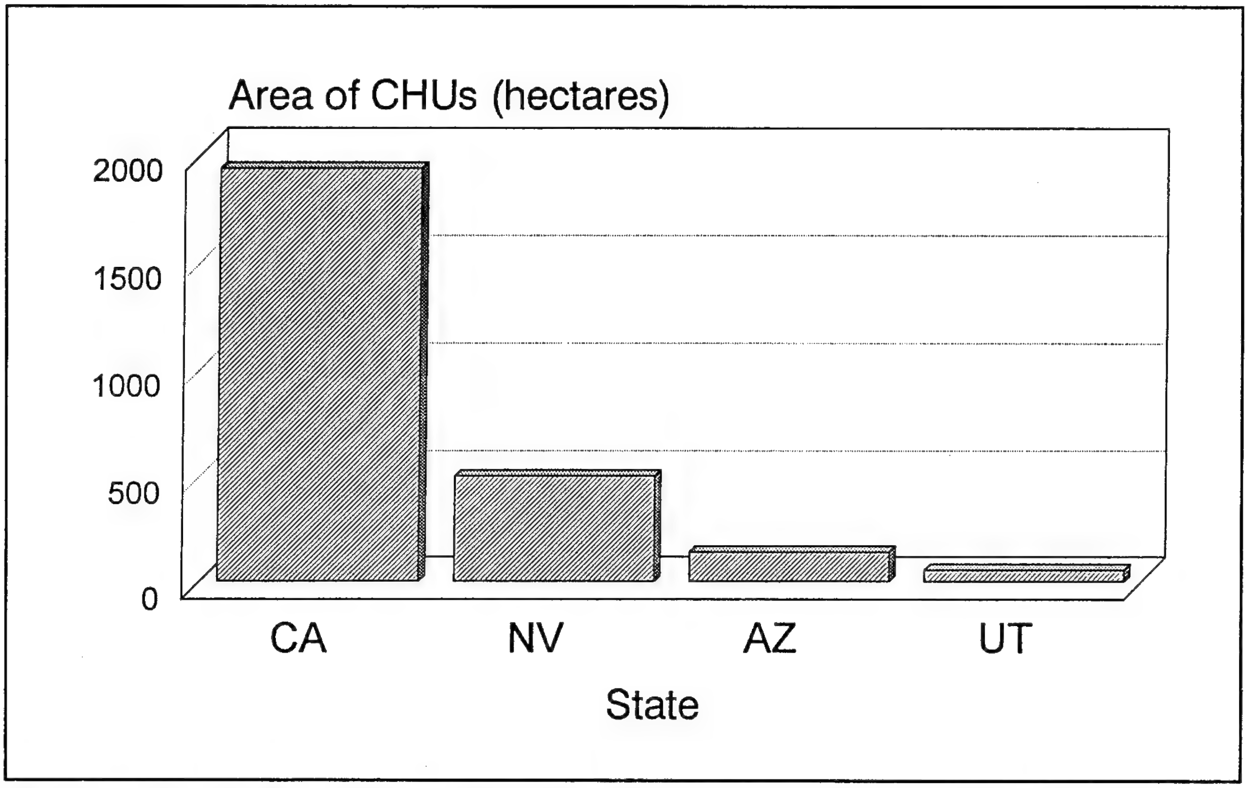


Figure 26. State distribution of the 12 Critical Habitat Units (CHUs) for the Mojave population of the Desert Tortoise.

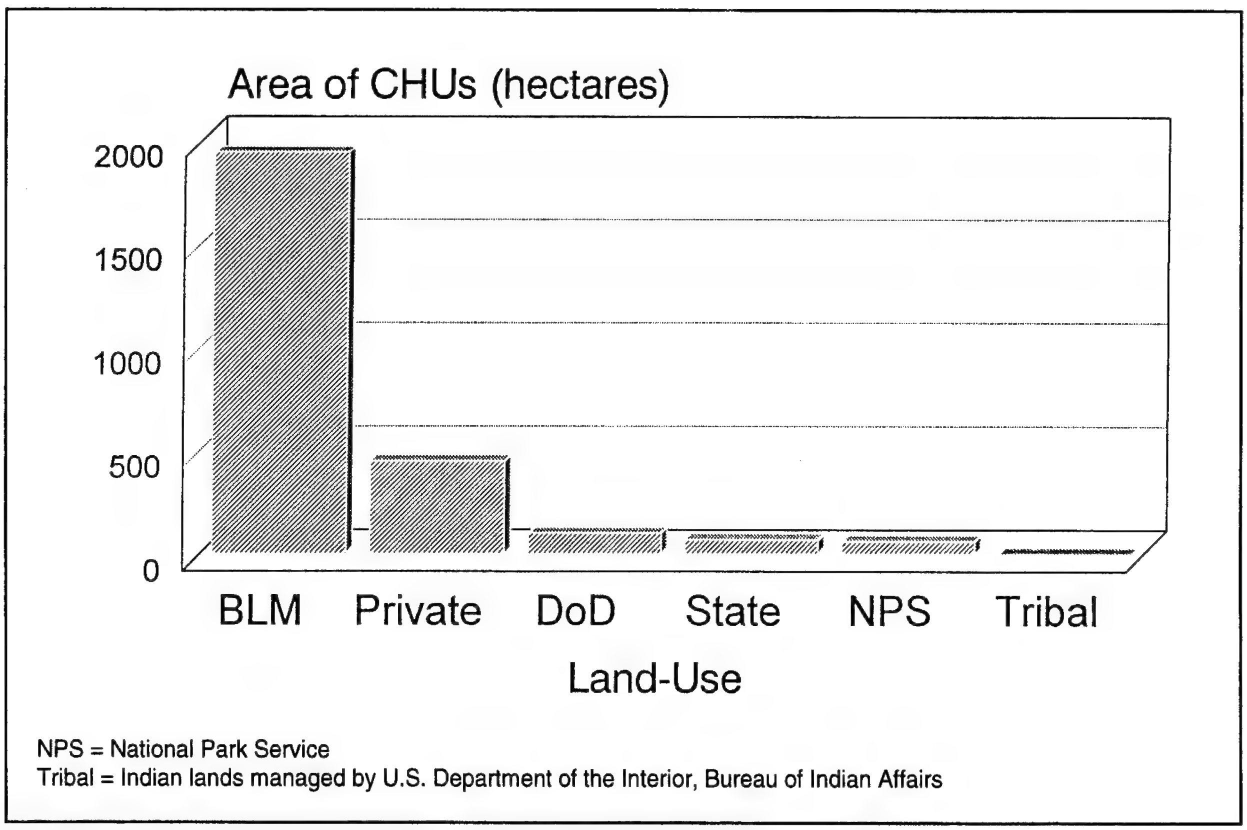


Figure 27. Land-use distribution of the 12 Critical Habitat Units (CHUs) for the Mojave population of the Desert Tortoise.

4 percent (98,017 ha [3.76 percent]) of identified critical habitat is located on military installations. Most CHUs are in California on public lands managed by the U.S. Department of the Interior, Bureau of Land Management. The following discussion will be limited to the four large DoD installations in the Mojave Desert. An eastern and southeastern parcel of Edwards Air Force Base is included as a small portion of the Fremont-Kramer CHU (209,631 ha) in its southwest corner. The northern boundary of the Superior-Cronese CHU (310,360 ha) runs directly along the entire southern and southwest boundary of Fort Irwin, and also along the south boundary of Naval Air Weapons Station, China Lake, Mojave B Ranges. This CHU was directly responsible for preventing the proposed NTC land expansion to the south and west. The Pinto Mountain CHU (69,486 ha) mainly consists of the Joshua Tree National Monument, and lies south of State Highway 62. The south boundary of Marine Corps Air Ground Combat Center is located 5 km north of SH 62. There is a good possibility of genetic integrity between tortoises in the Indian Cove population at JTNM and the Sand Hill population on the Marine base (E. Hutchinson, personnel communication, 1994). Sand Hill tortoises represent the largest population on the MCAGCC, and tortoises and their habitat are completely protected.

The Desert Tortoise Recovery Plan was published in June 1994 (U.S. Fish and Wildlife Service 1994a). The recovery plan recommended the establishment of 14 Desert Wildlife Management Areas (DWMAs) in the Mojave and Colorado Deserts (U.S. Fish and Wildlife Service 1994b). Three DWMAs are in some way relevant to Mojave military installations and were discussed above: Fremont-Kramer, Superior-Cronese, and Pinto Mountain CHU (renamed Joshua Tree DWMA). An important implication of the establishment of the DWMAs, besides protection of the viability of Desert Tortoise populations, is the concurrent protection of biodiversity—the maintenance of habitat for other herpetofauna, mammals, birds, invertebrates, and plants. The DWMAs represent the protection of ecosystem viability. A thorough review of the ecology and biogeography of the 14 DWMAs in an ecoregional context and their significance to Mojave and Colorado Desert military installations will be addressed in future research.

6 Desert Tortoise Management Potentials at Fort Irwin

The Ecological Significance of the Desert Tortoise on Fort Irwin

The BLM has recommended that portions of the Mojave Desert with low Desert Tortoise densities should receive minimal management or considerations for this species, and mitigation efforts for harmful activities should be minimal or not attempted (BLM 1988, 1989b). Berry (1984, 1989) considers tortoise populations of less than 20 per sq mi as not viable, and therefore insignificant for management considerations. The author believes that these two views are overly pessimistic. First, in most tortoise density estimates, densities are based on "standard transect" sign counts. As discussed previously, these counts are subject to high variability and potential underestimation. Habitats containing lower tortoise densities are important for gene flow, reduced fragmentation, and population recruitment. Historical estimates of tortoise densities by Berry and others (see "Population Trends" in Chapter 3) are probably overinflated, and low densities in many portions of the tortoise's range—particularly as estimated by the transect method—may be natural and typical. According to the perspective documented in this report, all eight Fort Irwin tortoise sites identified in 1989 contain viable Desert Tortoise gene pools. The U.S. Fish and Wildlife Service (1990) also recommends that low-density populations of the Desert Tortoise should not be ignored in land management decisions.

Fort Irwin is centrally located with respect to Desert Tortoise populations in the Mojave Desert, and represents the northeast portion of the western Mojave subpopulation. Table 11 gives estimated tortoise densities in the Fort Irwin region calculated from Luckenbach's (1982) and the author's data. Fort Irwin's tortoises and habitats are important for the maintenance of genetic integrity among these populations, as well as those further into the western, southern, northeastern, and southeastern Mojave Desert. The large and dense population in the southern portion of the installation is particularly important, and this area possesses high-quality habitat. The elimination of tortoises within Fort Irwin not only reduces the total number of tortoises and habitat, but it fragments overall tortoise habitat and populations in the central Mojave Desert. Habitat and population fragmentation increases the probability of local extinctions. (See "Habitat Fragmentation" in Chapter 4.)

Table 11. Estimated mean Desert Tortoise densities in the Fort Irwin region.

Survey Site	Number of Transects	Total Length (km)	Estimated Mean Tortoise Density
Southwest of Fort Irwin (L)	10	64	217
Southeast of Fort Irwin (L)	6	38	98
South of China Lake (L)	12	77	172
Southeast of Barstow (L)	11	70	126
Hinkley (NW Barstow) (L)	5	32	264
Paradise Valley (K) (SW Paradise Range)	11	33	150

(L) = 1973-1975 data calculated from Luckenbach (1982)
(K) = 1988 data from Krzysik.
All tortoise densities were estimated by counting active tortoise burrows and dividing by two.

Fort Irwin tortoises appear to be free of the Upper Respiratory Tract Disease (URTD) that has been fatally affecting tortoises in many parts of the Mojave Desert (especially in the western Mojave). Symptoms resembling URTD have never been observed in tortoises at Fort Irwin or vicinity despite extensive field work and observations of experienced field researchers (the author, P. Woodman, D. Morafka, T. Clark, D. Clark, and others). Symptoms resembling URTD has been observed in tortoises at Stoddard and Lucerne Valleys, 70–90 km south, and Fremont Peak, 70 km west of Fort Irwin (P. Woodman and A. Krzysik, personal observations, 1989–1990). A reasonable explanation for the absence of URTD symptoms in Fort Irwin tortoises is that unwanted captive tortoises are not released into the fort. There are three good reasons:

1. public access to Fort Irwin is restricted
2. Fort Irwin and surrounding habitats are relatively inaccessible and remote
3. tortoise owners probably believe that NTC training ranges are not suitable habitat for relocations.

The potential for the release of diseased captive tortoises into Fort Irwin remains low. Fort Irwin tortoises, therefore, represent an excellent source of disease-free tortoises. However, the long-term effects on the viability of Mojave Desert tortoise populations due to URTD—as well as the heavy mortality in some tortoise populations—is unknown. Tortoise mortality has been very severe at the Desert Tortoise Natural Area (Craig Knowles, wildlife consultant, and P. Woodman, personal observations, 1990). This area traditionally contained the highest-density populations in the Mojave Desert. Reported symptoms of URTD have been most prevalent in the western Mojave

Desert. Therefore, the tortoise populations at Fort Irwin and vicinity represent a healthy gene pool in the western Mojave. It is possible that, at a future date, disease-free tortoises may be necessary for repatriations—the "release of individuals of a species into an area formally or currently occupied by that species" (Dodd and Seigel 1991) into habitats where local extinctions have occurred from URTD or other catastrophes.

Desert Tortoises protected on Fort Irwin may represent more viable populations than those on adjacent BLM or private lands. Because public access to Fort Irwin is restricted, protected tortoises and their habitat would not be subjected to off-road vehicles and human vandalism. Documented human abuses include captures for pets, and shootings for sport or eating. The habitat would also be protected from urbanization, agriculture, grazing, mining.

The remaining Desert Tortoise populations on Fort Irwin represent an excellent and unique opportunity to initiate research programs to investigate severe deficiencies in tortoise natural history and to examine management potentials in an environment of severe off-road vehicle use. This data would be invaluable for the Department of Defense, BLM, and the U.S. Fish and Wildlife Service for making multiple-use land management decisions, and for providing guidelines for tortoise management in the California Desert and elsewhere. The already-isolated populations of tortoises on Fort Irwin represent an unparalleled opportunity to monitor ecological and genetic parameters, as well as the ecophysiology of fragmented K-selected metapopulations.

Relocation Potential for Desert Tortoises

The relocation of resident individual animals is frequently envisioned as a potential solution or mitigation effort whenever habitats are being degraded or destroyed. Although favored by the public, biologists generally express negative opinions about relocation programs (Campbell 1980; British Herpetological Society 1983; Scott and Carpenter 1987; Conant 1988; Griffith et al. 1989; Mlot 1989; Tasse 1989; Dodd and Seigel 1991; Reinert 1991; but see the review in Burke 1991). Individual relocations have been unfavorable from both biological and economic perspectives. The benefit-to-cost ratio is almost always too low. Relocations are generally not successful for a variety of ecological reasons. Depending on the species, resident animals may possess a territory, and they are intimately familiar with their environment within their home ranges. A critical aspect of this environment is social interactions with other members of the species, both intra- and intersexual. Establishing and becoming familiar with its home range enables an animal to locate food and water, avoid predators, and find shelter. Individual animals taken from their established and learned environments

are at a distinct disadvantage in their new surroundings, even if they are relocated into suitable habitat, and even if they face no competition or agonistic (aggressive) behavior from established residents—both of which conditions are unlikely. It is difficult even to identify suitable habitat for relocating individuals—there is a real danger of relocation into unsuitable or suboptimal habitat. Adequate knowledge of habitat and ecological requirements for most species—including important aspects of life-history—is insufficient.

When animals are relocated into suitable habitat there usually will be competition from established (and possibly aggressive) territorial residents. Social adjustments in both residents and relocated animals are stressful, particularly in harsh environments. In most cases, the habitat will not have the capacity to support additional individuals, particularly if the habitat is degraded. Overstocking is detrimental to residents, but even more so to the transplanted individuals. Food, nesting sites, or shelter resources may be the limiting factor, but predation may also be important because predators often concentrate their efforts where food availability is high and when prey are unfamiliar with their surroundings. Of course, transplanting animals into habitats without intraspecific competitors is not a logical option because these habitats are ecologically unsuitable for the species. An exception would be if the habitat is below carrying capacity or a local extinction occurred. However, in this scenario (repatriation), the habitat capacity would have to be enhanced or restored, or the cause of the extinction/population loss determined and corrected. Neither the high level of ecological sophistication not the database necessary for such an assessment is available.

Another important consequence of relocations, but one that seems never to be considered, is the potential of introducing new genotypes into resident populations. Local populations (demes) have evolved coadapted gene complexes that improve population fitness to the local environment. The influx of novel gene complexes adapted to a different local environment could disrupt the fitness and uniqueness of the resident population's gene pool (see Krzysik 1994a).

The above discussion applies hypothetically to any species in general. However, all concerns discussed directly apply to the Desert Tortoise.

Berry (1973, 1975) has reported that tortoise relocation projects are politically difficult and biologically complex. Desert Tortoises display aggressive behavior, and social structure and interactions. Territoriality and dominance hierarchies appear to be particularly significant and important in tortoise populations (K. Berry, personal communication, 1990). The behavior and movements of relocated tortoises have been unpredictable, but tortoises display a strong homing ability, and have dispersed

straight-line distances of 6.6 km (Berry 1986b). Adult males are more aggressive, more active, and range further than females or juveniles. Berry (1974) reported that Desert Tortoises typically travel 470–823 m per day within their home ranges, with males occasionally travelling over 1000 m per day. Measured home ranges in Mojave Desert tortoises have varied from 1–89 ha (summarized in Berry 1986b). This indicates a radius of activity of 56–532 m, assuming a circular home range.

Tortoises have been documented to possess a remarkable knowledge of the location of resources within their home ranges: forage, cover sites and burrows, mineral licks, drinking water catchments, and mates (references in Berry 1986b). A relocated tortoise can no longer readily locate these necessary resources. Furthermore, the relocated tortoise must dig new burrows, handle aggressive behavior from resident tortoises, and exhibits the homing tendencies noted above. All these factors require energy and are stressful for the tortoise in an unfamiliar environment. The low success of tortoise relocation programs is understandable.

Goldstone often has been suggested as a relocation site for NTC Desert Tortoises since the habitat is not damaged and off-road impacts are low. However, at Goldstone, tortoises are only found in appreciable numbers at the southern end of Goldstone Lake. The remainder of Goldstone is apparently unsuitable for the Desert Tortoise. The exact nature of the unsuitability is unknown, but is probably dependent on the interaction of several environmental factors. These factors are discussed under "Other Comparisons" in Chapter 5.

The relocation of Desert Tortoises from the NTC should not be attempted until a research program is designed and implemented to address all potential relocation concerns. The data from such a study will prove to be very valuable for Department of Defense and BLM, as well as other agencies, since research has been inadequate in this area. However, the U.S. Fish and Wildlife Service is currently conducting research in relocating Desert Tortoises.

Desert Tortoise Management Strategies at Fort Irwin

Direct protection should be given to the 83 percent of Fort Irwin's tortoise population that resides in the eight tortoise sites identified in the 1989 survey. These tortoise sites could be called Desert Tortoise Management Zones (DTMZs). All eight sites occupy a total of 362 sq km and represent 14 percent of the installation's area. The DTMZs represent 40 percent of the landscape occupied by tortoises on the fort. The remaining 60 percent of the installation cannot effectively be managed for tortoises without jeopardizing NTC's training mission—a mission that is necessary for national

security. Although the "60 percent" area is large—551 sq km—it contains only 16 percent of Fort Irwin's tortoises, and tortoise populations there are continuing to decline because of extensive and continuing habitat deterioration from military exercises. The trainers landscape for military tactical vehicles at the NTC cannot be considered viable habitat for the Desert Tortoise.

The intensity and nature of the NTC mission is incompatible with the maintenance of viable Desert Tortoise populations on the actual training ranges. The detrimental impacts include: habitat loss, burrow destruction, and direct mortality. The only mechanism to protect tortoise populations is to isolate them from training exercises—particularly from off-road tactical vehicles.

The eight DTMZs can be protected because of their locations on the installation. Three sites—SL, SW, and E—are adjacent to fort boundaries. Sites GE, GW, and T are on bajadas against mountain ranges. Sites GO and F are already off limits to tactical vehicles. The nature of the protection for specific tortoise sites would depend on the ecological importance of the site as well as NTC training needs. Four levels of protection could be used for Fort Irwin's DTMZs:

- *Level 1*—complete protection of the site. The area would be off limits to tactical vehicles and all training missions. A 1 km buffer zone would be in place to insulate this protected zone from training activities. The buffer zone would be given the same protection as Level 3. Maintenance vehicles and other occasional low-impact traffic would be limited to existing roads and trails.
- *Level 2*—complete protection of the site as for Level 1, but with no buffer zone.
- *Level 3*—tactical vehicles would be permitted to enter and traverse the site *only on one (or several) designated main roads*. This type of site would also be off limits to all training missions, and would include a 1 km buffer zone.
- *Level 4*—protection identical to Level 3, but with no buffer zone.

An educational system should be implemented on Fort Irwin to brief NTC, Goldstone, rotational, and contracted personnel—military and civilian—on the protection and management of threatened, endangered, and sensitive species and their habitats. The emphasis would be on defining and enforcing the four protection levels defined above. In order to enforce habitat protection measures, stringent monitoring and severe penalties for violations should be established.

Site GO is located on Goldstone and is therefore off limits to tactical vehicles. Goldstone should be declared a natural area and protected, because of the ecological value and importance of its habitats and wildlife. Vehicles should be restricted to existing roads and trails, and no new roads or trails should be constructed.

Construction activities should be limited *only to present developed areas*. No natural habitats, vegetation, or soils should be disturbed.

Site F is located at Fort Irwin's Multipurpose Range Complex. No new target pads, roads, construction activities, or additional habitat disturbance should be permitted in the range. The MPRC should continue to function as a live-fire range. Maintenance vehicles should be limited to *existing roads only*.

Table 12 provides a summary of the protection recommended for the remaining six tortoise sites. Site SW is not only important for the Desert Tortoise, but the Mohave Ground Squirrel has been captured at this site, and two sensitive plant species are found there. The Lane Mountain Milk-vetch occurs in site SW and just to the west on BLM land. This locality and one near Barstow are the only known localities for this species. The other sensitive species is a subspecies or variety of Mojave indigo bush.

Table 12. Recommended protection strategy for the proposed Desert Tortoise Management Zones (DTMZs) at Fort Irwin. See text for definitions of protection levels.

DTMZ	Protection Level
SL	
L	1
ML	1
IM	3
GE	1
T	1
SW	2*
GW	4
E	4

*Trail through Lizard Gulch only.

The already off-limits sites GO and F represent 1.9 percent of Fort Irwin's landscape. Table 13 summarizes the size of the six DTMZs compared to the size of Fort Irwin. The comparison shows that 6.8 percent of Fort Irwin would be fully protected, with no training exercises or tactical vehicles permitted. An additional 7.3 percent would be protected from training exercises and off-road vehicles. Access through the area would be permitted, but only along designated main roads.

Interestingly, the Leach Lake Impact zone is the same size as the combined eight tortoise management zones (369 km^2 vs 362 km^2). If the NTC could recover this

Table 13. Summary of the size of DTMZs compared to the size of Fort Irwin.

Protection Strategy	Sites Involved	Size (sq km)	Percent of Fort Irwin
Off-limits	L, ML, GE, T, SW	176	6.8
Travel ONLY on designated roads	IM, GW, E	137	5.3
Buffers zones	L, ML, IM, GE, T	53	2.0

impact zone from the Air Force for training purposes, the implementation of DTMZs would cause no net loss of training land.

Desert Tortoise Mitigation and Research Needs at Fort Irwin

Several mitigation measures have been identified that would benefit the Desert Tortoise on Fort Irwin.

A Desert Tortoise educational program should be implemented at Fort Irwin. The program should include environmental awareness on the handling of tortoises, impacts of off-road and tactical vehicle use, and other wildlife and habitat concerns.

A research program should be initiated to investigate fundamental and important problems concerning Desert Tortoise Biology, Ecology and Management. Important topics include:

- developing a new technology for more accurate, precise, and economic methods for estimating tortoise densities
- incorporating geographic information system (GIS) and spatial analysis technologies for assessing and monitoring tortoise distribution and density patterns, and to support more effective natural resources management decisions*
- developing multivariate tortoise-habitat models, and integrating them with GIS technology
- conducting comparative research on the biology and ecology of tortoises in a gradient of trained to undisturbed landscapes
- investigating the ecological, biogeographical, genetic significance, and metapopulation dynamics of low-density tortoise populations
- monitoring the biology and ecology of isolated tortoise metapopulations, especially life-history parameters, genetics, and ecophysiology
- monitoring the effects of habitat degradation from tactical vehicles and its effect on resident tortoise populations.

* The Ecological Modeling and Risk Assessment Team at USACERL is currently developing spatial analysis tools to assess, monitor, and model Desert Tortoise distribution and density patterns on landscape and regional scales (Krzysik et al. 1994; Westervelt et al. 1995).

7 Summary

Desert Tortoise populations on Fort Irwin that are located close to the boundaries of the installation, or high on bajadas against mountain ranges, or in areas not regularly used by tactical vehicles have remained stable despite 6 years of intense NTC training exercises. On the other hand, tortoise populations located in valleys and on bajadas used extensively by tactical vehicles have significantly declined.

The valleys and bajadas of Fort Irwin, south of the Granite Mountains and east of Goldstone, historically contained appropriate habitat for the Desert Tortoise, and this species undoubtedly was distributed continuously throughout most of the installation, with the exception of mountains, playas, and local areas of unsuitable soils. By 1983, the distribution of Fort Irwin's tortoise population was already patchy in the landscape after being subjected to a cumulative total of 35 years of military training activities. In 1989, additional fragmentation was evident. Tortoises probably always occurred at low densities on portions of Fort Irwin north of the Granites, where bajada elevations are 1000 to 1300 m.

Eight populations of Desert Tortoise were located on Fort Irwin in 1989. The location of these populations are referred to as sites. These sites occupy 362 km^2, or 14 percent of the installation. When data collected from tortoise surveys in 1983 were compared to 1989 data, five of these populations showed no significant change in estimated density. Two tortoise sites are located at installation boundaries. Training impacts at those sites are less than in the fort's interior, and immigration of tortoises from outside the installation is possible. Two other sites are on high bajadas against mountain ranges. Habitat damage and tactical vehicle traffic is lower in these more rugged areas, which contain steep-walled washes, than in the broad valleys below them. A fifth site was located in Goldstone—an area off limits to tactical vehicles—where no habitat changes have occurred.

A sixth resident tortoise population was found in the Multipurpose Range Complex, just east of Goldstone. The range complex consists of target pads and maintenance roads, and is not used by tactical vehicles. The small sampling effort in the 1983 census underestimated the density of tortoises at this site.

The two other tortoise populations found in 1989, including the largest and most important population, cannot be directly compared with 1983 data. Portions of these populations are found in impact zones that were not cleared until 1984-1985, and were therefore off limits for the 1983 surveys. These two sites were compared by deleting the impact zone portions from the 1989 data. One of these sites was the Granite Pass population, located between the Nelson and Lucky Fuse impact areas. The estimated tortoise density declined by 50 percent in this area between 1983 and 1989. The other population, and the largest one located on the fort both in terms of density and area, was found along the southern boundary of Fort Irwin between Fort Irwin Road and The Whale. Tortoises in this population represent the same gene pool, and are continuous with the high-density population located on BLM lands south of the installation. The 1983–1989 comparison included the area between Fort Irwin Road and the Langford impact area. Estimated tortoise densities were almost twice as high in 1989 as in 1983. Since the Langford impact area was cleared in 1984, tactical vehicle traffic has dramatically increased in the southern portion of the fort. The habitat quality in this area is very high, and habitat degradation—at least so far—has not been as extensive as in the training ranges located in the interior portions of the installation.

The major training area of Fort Irwin consists of the southern and central corridors. This area was once high quality Desert Tortoise habitat, but even in 1983 it was badly degraded. Tortoise densities declined by 62 percent in these valleys between 1983 and 1989. Similarly, the tortoise population declined by 81 percent in the northwestern portion of the fort. In contrast to the fort's main lower valleys, northwestern Fort Irwin may never have had an abundance of tortoises because the elevation there is mostly over 1000 m.

Paralleling the decline of the Desert Tortoise in Fort Irwin's major valleys, shrub cover decreased by 69 percent in the southern corridor valley between 1983 and 1989, while bajada shrub cover declined by 51 to 67 percent.

The total estimated number of Desert Tortoises on Fort Irwin in 1989 was 6597, ± 1285 individuals. Tortoise distribution and density in the fort are very patchy. Ninety-nine percent of the tortoises on Fort Irwin live on 35 percent of the landscape, 83 percent occupied 14 percent of the fort (the eight tortoise sites), while 50 percent were concentrated on only 5 percent of Fort Irwin's land area (site SL).

During the 1989 tortoise surveys on Fort Irwin, 44 adult and subadult tortoise carcasses were found on survey transects. Seventy percent of these carcasses were crushed, and 74 percent of the crushed carcasses were found in tank tracks. Although this is evidence of direct mortality by tactical vehicles, it cannot be surmised what

proportion of these tortoises were alive when they were crushed. Under natural conditions and in the absence of pathogenic infections (e.g., Upper Respiratory Tract Disease), Desert Tortoise mortality is low for adults and subadults.

Relocation of individual tortoises from degraded areas to more suitable habitats on or off the installation is not as viable of a potential solution as one might think. Relocated tortoises would have to compete for territory with the other individuals occupying that territory. The relocated individuals would be confronted with aggressive behavior from the native individuals, and would have to develop a whole new set of knowledge about the new landscape and its available resources. They also would probably have to dig new burrows—a large drain on individual resources in a stressful, competitive new environment. Furthermore, relocated individuals could harm the genetic integrity of the resident population by introducing novel gene complexes that would dilute evolved, coadapted genes that improve the resident population's fitness to the local environment.

The author has developed recommendations for Desert Tortoise management at Fort Irwin:

1. Define all eight Desert Tortoise population sites, comprising 40 percent of the installation (much of which is not used directly for training), as Desert Tortoise Management Zones (DTMZs)
2. Apply one of four levels of direct protection to each DTMZ
3. Do not directly protect the other 60 percent of Fort Irwin landscape—these training areas are vital to national security and cannot be considered viable habitat for Desert Tortoises
4. Establish an educational program on Desert Tortoise awareness to brief all personnel, including rotational and contracted personnel, military and civilian
5. Establish stringent monitoring and severe penalties to ensure protection of the DMTZs
6. Initiate research to investigate fundamental problems of Desert Tortoise biology, ecology, and management, including:

    - development of new technology for more precise and cost-effective ways to estimate Desert Tortoise densities
    - incorporation of GIS and spatial analysis technologies for monitoring and assessing tortoise populations and supporting Fort Irwin's natural resources management decisions
    - development of multivariate tortoise-habitat models and integrate with GIS technology

- conducting of comparative research on the biology and ecology of tortoises in habitats ranging from undisturbed to heavily utilized
- investigation of the ecological, biogeographical, genetic significance, and metapopulation dynamics of low-density tortoise populations
- monitoring the biology and ecology of isolated tortoise metapopulations, especially life-history parameters, genetics, and ecophysiology
- monitoring the effects of habitat degradation by tactical vehicles, and their effects on resident tortoise populations.

References

Cited

Adams, J.A., A.E. Endo, L.H. Stolzy, P.G. Rowlands, and H.B. Johnson. 1982. Controlled experiments on soil compaction produced by off-road vehicles in the Mojave Desert, California. J. Appl. Ecol. 19:167-175.

Alverson, W.S., W. Kuhlmann, and D.M. Waller. 1994. Wild Forests: Conservation Biology and Public Policy. Island Press, Washington, DC.

Andrews, R.N.L., and P.F. Nowak, eds. 1980. Off-road vehicle use: a management challenge. Sponsored by Off. Envir. Qual., U.S. Dept. Agric., School Nat. Res., Univ. Michigan, and Univ. Michigan Ext. Serv.

Auffenberg, W. 1969. Tortoise behavior and survival. Biol. Sci. Curric. Study, Patterns of Life Series. Rand McNally, Chicago, IL.

Avery, H.W. 1992. Summer food habits of desert tortoises in Ivanpah Valley, California. Abstract. Proc. Desert Tortoise Council Symp. 1992:60.

Avery, H.W., and K.H. Berry. 1991. Upper respiratory tract disease and high adult death rates in western Mojave tortoise populations, 1989-1990. Abstract. Proc. Desert Tortoise Council Symp. 1987-1991:281.

Beatley, T. 1994. Habitat Conservation Planning: Endangered Species and Urban Growth. univ. Texas Press. Austin, TX.

Berry, K.H. 1973. The magnitude of the required tortoise relocation project and an examination of potential relocation sites. Div. Highways, State of Calif., Contract F-9353.

Berry, K.H. 1974. Desert tortoise relocation project: status report for 1972. Div. Highways, State of Calif., Contract F-9353.

Berry, K.H. 1975. The desert tortoise relocation project: status report for 1974. Dept. Trans., State of Calif., Contract F-9353.

Berry, K.H. 1978. Livestock grazing and the desert tortoise. Trans. No. Amer. Wildl. Nat. Res. Conf. 43:505-519.

Berry, K.H., ed. 1984. The status of the desert tortoise (Gopherus agassizii) in the United States. Desert Tortoise Council Rep. to U.S. Fish and Wildl. Serv. on Purchase Order No. 11310-0083-81.

Berry, K.H. 1985. Avian predation on the desert tortoise (Gopherus agassizi) in California. U.S. Bur. Land Manage., Calif. Desert Dist., Riverside, CA. Rep. to So. Calif. Edison Co., Rosemead, CA.

Berry, K.H. 1986a. Incidence of gunshot deaths in desert tortoise populations in California. Wildl. Soc. Bull. 14:127-132.

Berry, K.H. 1986b. Desert tortoise (Gopherus agassizii) relocations: implications of social behavior and movements. Herpetologica 42:113-125.

Berry, K.H. 1989. Gopherus agassizii, desert tortoise. Pages 5-7 in The Conservation Biology of tortoises. I.R. Swingland and M.W. Klemens, eds. Occ. Pap. IUCN Species Survival Commission No. 5. Kelvyn Press, Inc. Broadview, IL.

Berry, K.H. 1991. Status of desert tortoise populations in California: The 1990 data set. Abstract. Proc. Desert Tortoise Council Symp. 1987-1991:282.

Berry, K.H. 1992. Relationships between tortoise population declines, levels of human use and impacts to habitats. Abstract. Proc. Desert Tortoise Council Symp. 1992:110.

Berry, K.H., and L.L. Nicholson. 1984. The distribution and density of desert tortoise populations in California in the 1970's. Pages 22-60 in The Status of the Desert Tortoise (Gopherus agassizii) in the United States. K.H. Berry, ed. Desert Tortoise Council Rep. to U.S. Fish and Wildl. Serv. on Purchase Order No. 11310-0083-81.

Berry, K.H., B.L. Burge, T. Shields, C. Knowles, and M. Paulissen. 1988. Trends in tortoise populations in California between 1979-1981 and 1987 with a focus on new data. Paper presented at The Desert Tortoise Council Symp., Laughlin, NV.

Berry, K.H., L.L. Nicholson, S. Juarez, and A.P. Woodman. 1986a. Changes in desert tortoise populations at four study sites in California. U.S. Bur. Land Manage. Rep., Calif. Desert Dist., Riverside, CA.

Berry, K.H., T. Shields, A.P. Woodman, T. Campbell, J. Robertson, K. Bohuski, and A. Karl. 1986b. Changes in desert tortoise populations at the Desert Tortoise Research Natural Area between 1979 and 1985. U.S. Bur. Land Manage. Rep., Calif. Desert Dist., Riverside, CA.

Berry, K.H., and S. Slone. 1989. Final notes from Meeting on Upper Respiratory Disease Syndrome in Desert Tortoises. October 12-13, 1989. U.S. Bur. Land Manage., Calif. Desert Dist., Riverside, CA.

Berry, K.H., A.P. Woodman, K.E. Bohuski, and T. Shields. 1987. Changes in tortoise populations in the Lucerne, Johnson, and Ivanpah Valleys of California between 1979-1980 and 1986. Paper presented at The Desert Tortoise Council Symp., Las Vegas, NV.

Berry, K.H., and H.W. Avery. 1991. Distribution of shell disease/necrosis in tortoise populations in the Chuckwalla Bench and elsewhere in California. Abstract. Proc. Desert Tortoise Council Symp. 1987-1991:283.

Berry, K.H., T. Shields, G. Goodlett, S. Boland, R. Gumtow, P.R. Knowles, and C.T. Knowles. 1990. Continued declines of tortoise populations in the western Mojave Desert: Results of 1989 surveys at the Desert Tortoise Natural Area Interpretive Center and Fremont Peak. Abstract. Proc. Desert Tortoise Council Symp. 1987-1991:219.

Berry, K.H., A.P. Woodman, and C.J. Knowles. 1989. Ten years of monitoring data from the Desert Tortoise Natural Area interior, Chuckwalla Bench Area of Critical Environmental Concern, and Chemehuevi Valley. Abstract. Proc. Desert Tortoise Council Symp. 1987-1991:162.

Biosystems Analysis, Inc. 1990. Desert Tortoise Review, Draft. Analysis submitted for inclusion in administrative record on January 18, 1990 by Sports Committee District 37 of the AMA and the California Desert Coalition. Represented by The Flanagan Group, Alexandria, VA.

BLM. 1988. Recommendations for management of the desert tortoise in the California Desert. U.S. Bur. Land Manage., Calif. Desert Dist., Riverside, CA.

BLM. 1989a. Environmental assessment for the selected control of the common raven to reduce desert tortoise predation in the Mojave Desert, California. U.S. Bur. Land Manage., Calif. Desert Dist., Riverside, CA.

BLM. 1989b. Interim directives for management of desert tortoise habitat on public lands in California. U.S. Bur. Land Manage., Calif. Desert Dist., Riverside, CA.

BLM. 1990a. Draft environmental impact statement for the management of the common raven in the California Desert Conservation Area. U.S. Bur. Land Manage., Calif. Desert Dist., Riverside, CA.

BLM. 1990b. Draft raven management plan for the California Desert Conservation Area. U.S. Bur. Land Manage., Calif. Dept. Fish and Game, U.S. Fish and Wildl. Serv.

Boarman, W.I. 1992. The raven management program of the Bureau of Land Management: Status as of 1992. Proc. Desert Tortoise Council Symp. 1992:113-116.

Bolger, D.P. 1986. Dragons at War: 2-34th Infantry in the Mojave. Presidio Press. Novato, CA.

British Herpetological Society. 1983. Herpetofauna translocations in Britain - A policy. Brit. J. Herpetol. 6:314-316.

Bull, J.J. 1980. Sex determination in reptiles. Quar. Rev. Biol. 55:3-21.

Bull, J.J. 1985. Sex ratio and nest temperature in turtles: comparing field and laboratory data. Ecology 66:1115-1122.

Bull, J.J., and R.C. Vogt. 1979. Temperature-dependent sex determination in turtles. Science 206:1186-1188.

Burge, B.L. 1977. Movements and behavior of the desert tortoise (Gopherus agassizii). M.S. Thesis. Univ. Nevada. Las Vegas, NV.

Burge, B.L., and W.G. Bradley. 1976. Population density, structure and feeding habits of the desert tortoise, Gopherus agassizii, in a low desert study area in southern Nevada. Proc. Symp., The Desert Tortoise Council Symp. 1976:51-74.

Burgess, R.L., and D.M. Sharpe, eds. 1981. Forest Island Dynamics in Man-Dominated Landscapes. Springer-Verlag. New York, NY.

Burke, R.L. 1991. Relocations, repatriations, and translocations of amphibians and reptiles: Taking a broader view. Herpetologica 47:350-357.

Bury, R.B., T.C. Esque, and P.S. Corn. 1988. Conservation of desert tortoises (Gopherus agassizii). Genetics and protection of isolated populations. Proc. Desert Tortoise Symp. 1988:59-66.

Bury, R.B., R.A. Luckenbach, and S.D. Busack. 1977. Effects of off-road vehicles on vertebrates in the California desert. Wildl. Res. Rep. 8. U.S. Fish and Wildl. Serv.

Bury, R.B., R.A. Luckenbach, and L.R. Munoz. 1978. Observation on Gopherus agassizii from Isla Tiburon, Sierra, Mexico. Proc. Symp., The Desert Tortoise Council Symp. 1978:69-72.

Busack, S.D. and R.B. Bury. 1974. Some effects of off-road vehicles and sheep grazing on lizard populations in the Mojave Desert. Biol. Conserv. 6:179-183.

Camp, R.J., R.L. Knight, H.A.L. Knight, and M.W. Sherman, 1992. Food habits of nesting common ravens in the eastern Mojave Desert. Abstract. Proc. Desert Tortoise Council Symp. 1992-:117.

Campbell, S. 1980. Is reintroduction a realistic goal? Pages 263-269 in Conservation Biology: An Evolutionary-Ecological Perspective. M.E. Soule and B.A. Wilcox, eds. Sinauer Assoc., Inc. Sunderland, MA.

Conant, S. 1988. Saving endangered species by translocation. Bioscience 38:254-257.

Coombs, E.M. 1979. Food habits and livestock competition with the desert tortoise on the Beaver Dam Slope, Utah. Proc., Desert Tortoise Council Symp. 1979:132-147.

Congdon, J.D., and J.W. Gibbons. 1983. Relationships of reproductive characteristics to body size in Pseudemys scipta. Herpetologica 39:147-151.

Crumly, C.R. 1984. The genus name for North American Gopher tortoises. Proc., Desert Tortoise Council Symp. 1984:147-148.

Crumly, C.R. 1988. A nomenclatural history of tortoises (Family Testudinidae). Smithsonian Herpetological Information Service No. 75. Division of Amphibians and Reptiles, Nat. Mus. Nat. Hist., Smithsonian Inst. Washington, DC.

Desert Tortoise Council. 1992. Proc. Desert Tortoise Council Symp. 1992:7-58.

Dodd, C.K. Jr. 1986. Desert and gopher tortoise perspectives on conservation approaches. Pages 54-72 in The gopher tortoise and its community. D. R. Jackson and R. J. Bryant, eds. Proc. 5th Ann. Mtg., Gopher Tortoise Council.

Dodd, C.K., Jr., and R.A. Seigel. 1991. Relocation, repatriation, and translocation of amphibians and reptiles: Are they conservation strategies that work? Herpetologica 47:336-350.

Ernst, C.H., and R.W. Barbour. 1972. Turtles of the United States. Univ. Press of Kentucky, Lexington, KY.

Esque, T.C., and R.B. Duncan. 1985. A population study of the desert tortoise (Gopherus agassizii) at the Sheep Mountain study plot in Nevada. Proc., Desert Tortoise Council Symp. 1985:47-67.

Esque, T.C. 1994. Diet and Diet Selection of the Desert Tortoise (Gopherus agassizii) in the northeast Mojave Desert. M.S. Thesis. Coloratio State University, Fort Collins, CO.

Farrell, J. 1989. Some natural history observations of raven behavior and predation on desert tortoises. Abstract. Proc. Desert Tortoise Council Symp. 1987-1991:168.

Federal Register. 1994. Determination of Critical Habitat for the Mojave Population of the Desert Tortoise; Final Rule. Dept. of Interior, Fish and Wildlife Service 59(26):5820-5865, and Corrections 59(37):9032-9036.

Ferguson, D., and N. Ferguson. 1983. Sacred Cows at the Public Trough. Maverick Books, Bend, OR.

Fradkin, P. 1979. The eating of the west. Audobon 81:94-121.

Fitch, H.S. 1970. Reproductive cycles in lizards and snakes. Univ. Kanas Mus. Nat. Hist. Publ. 52:1-247.

Gibbons, J.W. 1982. Reproductive patterns in freshwater turtles. Herpetologica 38:222-227.

Gibbons, J.W., G.H. Keaton, J.P. Schubauer, J.L. Greene, N.H. Bennett, J.P. McAuliffe, and R.R. Sharitz. 1979. Unusual population size structure in freshwater turtles on barrier islands. Georgia J. Sci. 37:155-159.

Gibbons, J.W., J.L. Greene, and K.K. Patterson. 1982. Variation in reproductive characteristics of aquatic turtles. Copeia 1982:776-784.

Glenn, J.L. 1983. A note on the longevity of a captive desert tortoise (Gopherus agassizii). Proc., Desert Tortoise Council Symp. 1983:131-132.

Grant, C. 1936. The southwestern desert tortoise: Gopherus agassizii. Zoologica 21:225-229.

Griffith, B., J.M. Scott, J.W. Carpenter, and C. Reed. 1989. Translocation as a species conservation tool: Status and strategy. Science 245:477-480.

Halberstadt, H. 1989. NTC: A Primer of Modern Land Combat. Presidio Press. Novato, CA.

Harris, L.D. 1984. The Fragmented Forest: Island Biogeography Theory and the Preservation of Biotic Diversity. Univ. Chicago Press. Chicago, IL.

Hickman, J.C., ed. 1993. The Jepson Manual: Higher Plants of California. Univ. California Press, Berkeley, CA.

Hobbs, R.J., and L.F. Huenneke. 1992. Disturbance, diversity, and invasion: Implications for conservation. Conserv. Biol. 6:324-337.

Hohman, J.P., R.D. Ohwart, and J. Schwartzmann. 1980. An annotated bibliography of the desert tortoise (Gopherus agassizii). The Desert Tortoise Council, Spec. Pub. No. 1.

Jacobson, E., and J. Gaskin. 1990. Clinicopathologic investigations on an upper respiratory disease of free-ranging desert tortoises, Xerobates agassizii. Final Rep. on Contract No. CA950-CT9-23 to U.S. Bur. Land Manage., Calif. Desert Dist., Riverside, CA.

Jacobson, E.R. 1991. Shell necrosis in the desert tortoise population at Chuckwalla Bench, Riverside County, California. Abstract. Proc. Desert Tortoise Council Symp. Abstract. 1987-1991:325.

Jacobsen, E.R., B.R. Collins, I.M. Fuerst, M.B. Brown, P.A. Klein, and R.K. Harris. 1992. Clinicopathologic evaluations on desert tortoise (Gopherus agassizii) with upper respiratory tract disease. Abstract. Proc. Desert Tortoise Council Symp. 1992:47.

Jacobsen, E.R., J.M. Gaskin, M.B. Brown, R.K. Harris, C.H. Gardiner, J.L. LaPointe, H.P. Adams, and C. Reggiardo. 1991. Chronic upper respiratory tract disease of free-ranging desert tortoises (Xerobates agassizi). J. Wildl. Diseases 27:296-316.

Jennings, R.D. 1985. Biochemical variation of the desert tortoise, Gopherus agassizi. M.S. Thesis. Univ. New Mexico. Albuequerque, NM.

Jennings, W.B., and C.L. Fontenot, Jr. 1992. Observations on the feeding behavior of desert tortoises (Gopherus agassizii) at the Desert Tortoise Research Natural Area, Kern County, California. Proc. Desert Tortoise Council Symp. 1992:69-81.

Joyner-Griffith, M. 1991. Egg production and hatching success in the desert tortoise (Gopherus agassizii). Abstract. Proc. Desert Tortoise Council Symp. 1987-1991:327.

King, F.W. and R.L. Burke, eds. 1989. Crocodilian, tuatara, and turtle species of the world. A taxonomic and geographic reference. Association of Systematics Collections. Washington, DC.

Knowles, C., and P. Knowles. 1989. A survey for diseased desert tortoises in and near the Desert Tortoise Natural Area, spring 1989. Report prepared by FaunaWest Wildlife Consultants for U.S. Bur. Land Manage., Calif. Desert Dist., Riverside, CA.

Knowles, C.J., and K.H. Berry. 1990. Relative abundance and distribution of the common raven in the deserts of southern California and Nevada, fall 1988 through summer 1989. Abstract. Proc. Desert Tortoise Council Symp. 1987-1991:247.

Knowles, C.J., P.R. Knowles, and K.H. Berry. 1990. A survey for ill desert tortoises in and near the Desert Tortoise Natural Area during spring 1989. Abstract. Proc. Desert Tortoise Council Symp. 1987-1991:248.

Krzysik, A.J. 1984. Habitat relationships and the effects of environmental impacts on the bird and small mammal communities of the central Mojave Desert. Pages 358-394 in Proceedings - Workshop On Management of Nongame Species and Ecological Communities. W. C. McComb, ed. University of Kentucky, Lexington, Kentucky.

Krzysik, A.J. 1985. Ecological assessment of the effects of Army training activities on a desert ecosystem: National Training Center, Fort Irwin, California. U.S. Army Corp of Engineers, Construction Engineering Research Laboratory (USACERL), Technical Report N-85/13, Champaign, IL.

Krzysik, A.J. 1987. Environmental gradient analysis, ordination, and classification in environmental impact assessments. USACERL Technical Report N-87/19. 121pp.

Krzysik, A.J. 1989. Birds in human modified environments and bird damage control: Social, economic, and health implications. USACERL Technical Report N-90/03. 189pp.

Krzysik, A.J. 1990. Biological assessment of threatened, endangered, and sensitive animals and plants on Fort Irwin, California: National Training Center and Goldstone Deep Space Communications Complex. Report to Fort Irwin (NTC) and U.S. Army FORSCOM. 146pp.

Krzysik, A.J. 1991. Ecological assessment of military training effects on threatened, endangered, and sensitive animals and plants at Fort Irwin, California. Report to Fort Irwin (NTC) and U.S. Army FORSCOM. 171pp.

Krzysik, A.J. 1993. Desert tortoise populations in the Mojave Desert and a half-centuty of military training activities. International Symposium: The Conservation, Restoration, and Management of Tortoises and Turtles. American Museum of Natural History. New York, NY. In press.

Krzysik, A.J. 1994a. Biodiversity and the threatened/endangered/sensitive species of Fort Irwin, California: The National Training Center mission, training effects, and options for natural rersources management and mitigation. USACERL Technical Report EN-94/07. 114pp.

Krzysik, A.J. 1994b. The Mohave ground squirrel at Fort Irwin, California: A State threatened species. USACERL Technical Report EN-94/09. 37pp.

Krzysik, A.J., K.C. Seel, S.A. Tweddale, J.D. Westerveld, and H. Mitasova. 1994. Thin-plate splines: A novel technology for modeling and monitoring desert tortoise populations on landscape and regional scales. Proc. Desert Tortoise Council Symp. 1994: In press.

Krzysik, A.J., and A.P. Woodman. 1991. Six years of Army training activities and the desert tortoise. Proc. Desert Tortoise Council Symp. 1987-1991:337-368.

Lamb, T., J.C. Avise, and J.W. Gibbons. 1989. Phylogeographic patterns in mitochondrial DNA of the desert tortoise (Xerobates agassizi), and evolutionary relationships among the North American gopher tortoises. Evolution 43:76-87.

Lampkin, W.H. 1966. Hatching tortoise eggs. Int. Turtle Tortoise Soc. J. 1:4-5.

Landers, J.L., J.A. Garner, and W.A. McRae. 1980. Reproduction of gopher tortoises (Gopherus polyphemus) in southwestern Georgia. Herpetologica 36:353-361.

Larson, A., D.B. Wake, and K.P. Yanev. 1984. Measuring gene flow among populations having high levels of genetic fragmentation. Genetics 106:293-308.

Luckenbach, R.A. 1978. An analysis of off-road vehicle use on desert avifaunas. Trans. No. Amer. Wildl. Nat. Res. Conf. 43:157-162.

Luckenbach, R.A. 1982. Ecology and management of the desert tortoise (Gopherus agassizii) in California. Pages 1-37 in North American Tortoises: Conservation and Management. R. B. Bury ed., U.S. Fish and Wildl. Serv., Wildl. Res. Rep. 12.

Luckenbach, R.A. and R.B. Bury. 1983. Effects of off-road vehicles on the biota of the Algodones Dunes, Imperial County, California. J. Appl. Ecol. 20:265-286.

McNaughton, S.J. 1993. Grasses and grazers, science and management. Ecol. Appl. 3:17-20.

Marlow, R.W. 1974. Preliminary report on the population dynamics in the desert tortoise (Gopherus agassizii) in the western Mojave Desert, California. Unpubl. Rep., Mus. Vert. Zool., Univ. Calif., Berkeley, CA.

Medica, P.A., R.D. Bury, and F.B. Turner. 1975. Growth of the desert tortoise (Gopherus agassizzi) in Nevada. Copeia 1975:639-643.

Medica, P.A., R.B. Bury, and R.A. Luckenbach. 1980. Drinking and construction of water catchments by the desert tortoise, Gopherus agassizii, in the Mojave Desert. Herpetologica 36:301-304.

Medica, P.A., C.L. Lyons, and F.B. Turner. 1982. A comparison of 1981 populations of the desert tortoise (Gopherus agassizi) in grazed and ungrazed areas in Ivanpah Valley, California. Rep. on Contract No. SS00012/UCLA, CA 950-1A1-1211 to U.S. Bur. Land Manage.

Miller, L. 1955. Further observations on the desert tortoise, Gopherus agassizii of California. Copeia 1955:113-118.

Miller, R.R., J.D. Williams, and J.E. Williams. 1989. Extinctions of North American fishes during the past century. Fisheries 14:22-38.

Minnick, J.E. 1977. Adaptive responses in the water and electrolyte budgets of native and captive desert tortoises, Gopherus agassizii, to chronic dought. Proc. Symp., The Desert Tortoise Council 1977:102-129.

Minnick, J.E. 1979a. Reptiles. Pages 391-641 in Compartive Physiology of Osmoregulation in Animals. G.M.O. Maloiy, ed. Academic Press. New York, NY.

Minnick, J.E. 1979b. Comparison of maintenance electrolyte budgets of free living desert and gopher tortoises (Gopherus agassizii and G. polyphenus). Proc. Desert Tortoise Council Symp. 1979:166-174.

Mlot, C. 1989. The science of saving endangered species. Bioscience 39:68-70.

Mooney, H.A., and J. Drake, eds. 1986. The ecology of biological invasions of Noth America and Hawaii. Springer-Verlag, New York, NY.

Mortimore, C. and P. Schneider. 1983. Population studies of the desert tortoise (Gopherus agassizii) in the Piute Valley study plot of southern Nevada. Nevada Dept. Wildl., Reno, NV.

Myers, N. 1980. Conversion of Tropical Moist Forests. National Academy of Sciences, Washington, DC.

Nagy, K.A. and P.A. Medica. 1986. Physiological ecology of desert tortoise in southern Nevada. Herpetologica 42:73-92.

National Research Council. 1980. Research Priorities in Tropical Biology. National Academy of Sciences. Washington, DC.

Nicholson, L.L. 1978. The effects of roads on desert tortoise populations. Proc., Desert Tortoise Council Symp. 1978:127-129.

Noss, R.F. 1983. A regional landscape aproach to maintain diversity. Bioscience 33:700-706.

Noss, R.F. 1987. Protecting natural areas in fragmented landscapes. Natural Areas Journal 7:2-13.

Prose, D.V. 1985. Persisting effects of armored military maneuvers on some soils of the Mojave Desert. Environ. Geol. Water Sci. J. 7:163-170.

Prose, D.V. 1986. Differences in soil compaction persisting in military vehicle tracks after 21 and 41 years. Proc. Pacific Div., Amer. Assoc. Adv. Sci. 5:43.

Prose, D.V., and S.K. Metzger. 1985. Recovery of soils and vegetation in World War II military base camps, Mojave Desert. U.S. Geol. Surv. Openfile Rep. 85-234.

Prose, D.V., and H.G. Wilshire. 1986. Long-term effects of military training exercises on soils and vegetation in the arid southwestern United States. Trans. Cong. Internat. Soc. Soil Sci. 2:136.

Rado, T. 1989. Proposed raven reduction program for 1989: A coordinated agency effort. Proc. Desert Tortoise Council Symp. 1987-1991:201-205.

Rado, T. 1990. Results of the 1989 pilot raven control program. Proc. Desert Tortoise Council Symp. 1987-1991:266-272.

Rainboth, W.J., D.G. Buth, and F.B. Turner. 1989. Allozyme variation in Mojave populations of the desert tortoise, Gopherus agassizi. Copeia 1989:115-123.

Reid, W.V., and K.R. Miller. 1989. Keeping Options Alive: The Scientific Basis for Conserving Biodiversity: Word Resources Institute. Washington, DC.

Reinert, H.K. 1991. Translocation as a conservation strategy for amphibians and reptiles: Some comments, concerns, and observations. Herpetologica 47:357-363.

Resource Concepts Inc. 1989. Livestock grazing and the desert tortoise-a briefing paper. Resource Concepts, Inc., Carson City, NV.

Rose, F.L. and F.U. Judd. 1982. Biology and status of Berlandier's tortoise (Gopherus berlandieri). Pages 57-70 in North American Tortoises: Conservation and Ecology. R. B. Bury, ed. U.S. Fish and Wildl. Serv., Wildl. Res. Rep. 12.

Rosskopp, W.J. Jr. 1988. Protocal for treating diseased tortoises (respiratory disease) at the Desert Tortoise Natural Area. Rep 1 to U.S. Bur. Land Manage., Calif. Desert Dist., Riverside, CA, under Contract No. CA950-CT8-51.

Scott, J.M., and J.W. Carpenter. 1987. Releases of captive-reared or translocated endangered birds: What do we need to know? Auk 104:544-545.

Shade, D. 1972. A hatching is recorded. Int. Turtle Tortoise Soc. J. 6:20-22.

Shoemaker, V.H., and K.A. Nagy. 1977. Osmoregulation in amphibians and reptiles. Amer. Rev. Physiol. 39:449-471.

Sokol, R.R., and F.J. Rohlf. 1969. Biometry. W.H. Freeman. San Francisco, CA.

Spotila, J.R., and E.A. Standora. 1986. Sex determination in the desert tortoise: a conservative management strategy is needed. Herpetologica 42:67-72.

Stenger, W. 1954. Beyond the Hundredth Meridian. Houghton Mifflin. Boston, MA.

Stewart, G.P. 1954. Observation on reproduction in the tortoise Gopherus agassizii in captivity. Copeia 1954:61-62.

Tasse, J. 1989. Translocation as a strategy for preserving endangered species. Endangered Species Upate 6(11-12):6.

Tomko, D.S. 1972. Autumn breeding of the desert tortoise. Copeia 1972:895.

Turner, F.B., and K.H. Berry. 1985. Population ecology of the desert tortoise at Goffs, California in 1984. Ann. Rep. to So. Calif. Edison Co., Res. and Dev. Ser. 85-RD-63.

Turner, F.B., P. Hayden, B.L. Burge, and J.B. Roberson. 1986. Egg production by the desert tortoise (Gopherus agassizii) in California. Herpetologica 42:93-104.

Turner, F.B., P.A. Medica, and C.L. Lyons. 1981. A comparison of populations of desert tortoises, Gopherus agassizi, in grazed and ungrazed areas in Ivanpah Valley, California. Proc. Symp., The Desert Tortoise Council 1981:139-162.

Turner, F.B., P.A. Medica, and C.L. Lyons. 1984. Reproduction and survival of the desert tortoise (Scaptochelys agassizii) in Ivanpah Valley, California. Copeia 1984:811-820.

U.S. Fish and Wildlife Service. 1988. Biological resource inventory, expansion of Fort Irwin National Training Center, San Bernardino County, California. Report to U.S. Army Corps of Engineers.

U.S. Fish and Wildlife Service. 1990. Assessment of biological information for listing the desert tortoise as an endangered species in the Mojave Desert. Predecision Document, U.S. Fish and Wildl. Serv., National Ecology Research Center, Fort Collins, CO.

U.S. Fish and Wildlife Service. 1994a. Desert tortoise (Mojave population) Recovery Plan. U.S. Fish and Wildlife Service, Portland, OR.

U.S. Fish and Wildlife Service. 1994b. Proposed desert wildlife management areas for recovery of the Mojave population of the desert tortoise. U.S. Fish and Wildlife Service, Portland, OR.

Wald, J., and D. Alberswerth. 1985. Our ailing public rangelands. National Wildlife Federation and Natural Resources Defence Council. Washington, DC.

Wald, J., and D. Alberswerth. 1989. Our ailing public rangelands: Still ailing. National Wildlife Federation and Natural Resources Defense Council. Washington, DC.

Wagner, F.H. 1978. Livestock grazing and the livestock industry. Pages 121-145 in H.P. Brokaw, ed. Wildlife and America. Council on Environmental Quality. Washington, DC.

Webb, R.H., and H.G. Wilshire, eds. 1983. Environmental Effects of Off-Road Vehicles: Impacts and Management in Arid Regions. Springer-Verlag. New York, NY.

Weinstein, M.N. 1989. Modeling desert tortoise habitat: can a useful management tool be developed from existing transect data? Ph.D. Dissertation. Univ. Calif. Los Angeles, CA.

Weinstein, M.N. and K.H. Berry. 1987. Morphometric analysis of desert tortoise populations. U.S. Bur. Land Manage., Calif. Desert Dist., Riverside, CA, Rep. on Contract No. CA950-CT7-003.

Weinstein, M.N., K.H. Berry, and F.B. Turner. 1987. An analysis of habitat relationships of the desert tortoise in California. Rep. for So. Calif. Edison Co., 87-RD-38.

Westervelt, J.D., A.J. Krzysik, and K. Seel. 1995. A neural network approach for converting field species density measurements to full-covered maps. Submitted for publication.

Wilcove, D.S., C.H. McLellan, and A.P. Dobson. 1986. Habitat fragmentation in the temperate zone. Pages 237-256 in Conservation Biology: The Science of Scarcity and Diversity. M.E. Soule, ed. Sinauer Assoc., Inc. Sunderland, MA.

Wilcox, B.A., and D.D. Murphy. 1985. Conservation strategy: The effects of fragmentation on extinction. Amer. Natur. 125:879-887.

Wilkinson, L. 1988. SYSTAT: The System for Statistics, SYGRAPH. Systat Inc. Evanston, IL.

Wilshire, H.G., and J.S. Nakata. 1976. Off-road vehicle effects on California's Mojave Desert. Calif. Geol. 29:123-132.

Wilson, R. 1989. The relationship between soil type and population densities of the desert tortoise (Gopherus agassizii). Abstract. Proc. Desert Tortoise Council Symp. 1987-1991:214.

Wilson, R.W., and R.D. Stager. 1989. Association between soils and desert tortoise population densities and distribution at Piute Valley Nevada. U.S. Bur. Land Manage., Las Vegas, NV.

Woodbury, A.M. and R. Hardy. 1948. Studies of the desert tortoise, Gopherus agassizii. Ecol. Mongr. 18:145-200.

Woodman, A.P. and S.M. Juarez. 1988. Juvenile desert tortoises utilized as primary prey of nesting common ravens near Kramer, California. Paper presented at The Desert Tortoise Council Symp., Las Vegas, NV.

Woodman, A.P., S.M. Juarez, E.D. Humphreys, K. Kirtland, and L.F. LaPre. 1986. Estimated density and distribution of the desert tortoise at Fort Irwin, National Training Center and Goldstone Space Communication Complex. Proc., Desert Tortoise Council Symp. 1986:81-99.

Wuerthner, G. 1992. Some ecological costs of livestock. Wild Earth 2:10-14.

USACERL DISTRIBUTION

Chief of Engineers
ATTN: CEHEC-IM-LH (2)
ATTN: CEHEC-IM-LP (2)
ATTN: CECG
ATTN: CECC-P
ATTN: CECC-R
ATTN: CECW
ATTN: CECW-O
ATTN: CECW-P
ATTN: CECW-PR
ATTN: CEMP
ATTN: CEMP-E
ATTN: CEMP-C
ATTN: CEMP-M
ATTN: CEMP-R
ATTN: CERD-C
ATTN: CERD-ZA
ATTN: CERD-L
ATTN: CERD-M
ATTN: CERM
ATTN: DAEN-ZC
ATTN: DAIM-FDP

US Army Engr District (Library)
ATTN: Fort Worth 76544
ATTN: Albuquerque 87103
ATTN: Los Angeles 90053
ATTN: San Francisco 94105
ATTN: Sacramento 95814

US Army Engr Division (Library)
ATTN: South Pacific 94111

US Army Materiel Command (AMC)
Alexandria, VA 22333-0001
ATTN: AMCEN-F
Installations:
Pueblo Depot Activity 81008
ATTN: SDSTE-PU-E
Dugway Proving Ground 8400\22
ATTN: STEDP-EN
Tooele Army Depot 84074
ATTN: SDSTE-IO
Yuma Proving Ground 85365
ATTN: STEYP-EH
White Sands Missile Range 88002
ATTN: STEWS-EL

FORSCOM
Forts Gillem & McPherson 30330
ATTN: FCEN-RDF
Installations:
Fort Ord 93941
ATTN: AFZW-DE
Fort Carson 80913
ATTN: AFZC-FE
Fort Irwin 92310
ATTN: AFZJ-EH
Fort Hood 76544
ATTN: AFZF-DE

TRADOC
Fort Monroe 23651
ATTN: ATBO-G
Installations:
Fort Huachuca 85613
ATTN: ATZS-EH

CEWES 39180
ATTN: Library

CECRL 03755
ATTN: Library

USA AMCOM
ATTN: Facilities Engr (3) 85613

US Army Envr Hygiene Agency
ATTN: HSHB-ME 21010

U.S. Army Environmental Center
ATTN: SFIM-AEC 21010-5401

Defense Tech Info Center 22304
ATTN: DTIC-FAB (2)

51
+72
9/94